

TENT COOPERATION TREATY

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents
United States Patent and Trademark
Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 11 April 2000 (11.04.00)	
International application No. PCT/US99/14439	Applicant's or agent's file reference 440110/PALL
International filing date (day/month/year) 29 June 1999 (29.06.99)	Priority date (day/month/year) 29 June 1998 (29.06.98)
Applicant WELCH, Thomas, C., Jr. et al	

1. The designated Office is hereby notified of its election made:

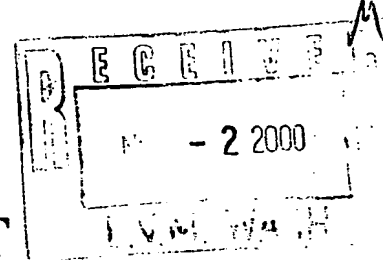
☒ in the demand filed with the International Preliminary Examining Authority on:27 January 2000 (27.01.00)☐ in a notice effecting later election filed with the International Bureau on:2. The election ☒ was☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer S. Mafla
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY



PCT

To: JOHN M. BELZ
LEYDIG, VOIT & MAYER, LTD.
700 THIRTEENTH STREET, N.W.
SUITE 300
WASHINGTON, DC 20005

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of Mailing
(day/month/year)

30 OCT 2000

Applicant's or agent's file reference

440110/PALL

IMPORTANT NOTIFICATION

International application No.

PCT/US99/14439

International filing date (day/month/year)

29 JUNE 1999

Priority Date (day/month/year)

29 JUNE 1998

Applicant

PALL CORPORATION

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.
2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.
3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. REMINDER

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/US

Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Authorized officer

RICHARD L. CHIESA

Facsimile No. (703) 305-3230

Telephone No. (703) 308-0661

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

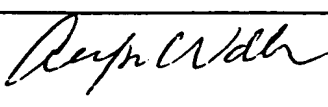
(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 440110/PALL	FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/US99/14439	International filing date (day/month/year) 29 JUNE 1999	Priority date (day/month/year) 29 JUNE 1998
International Patent Classification (IPC) or national classification and IPC IPC(7): B01D 46/10, 46/24 and US Cl.: 55/497, 498, 499, 500, 521, DIG 5		
Applicant PALL CORPORATION		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 6 sheets.
- ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority. (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).
- These annexes consist of a total of 2 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of report with regard to novelty, inventive step or industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☒ Certain documents cited
- VII ☒ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand 27 JANUARY 2000	Date of completion of this report 10 OCTOBER 2000
Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer  RICHARD L. CHIESI
Facsimile No. (703) 305-3230	Telephone No. (703) 308-0661

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/US99/14439

I. Basis of the report

1. With regard to the elements of the international application:*

☒ the international application as originally filed☒ the description:

pages 1-30, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____

☒ the claims:

pages 31-32, as originally filed
pages NONE, as amended (together with any statement) under Article 19
pages NONE, filed with the demand
pages NONE, filed with the letter of _____

☒ the drawings:

pages 1-11, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____

☒ the sequence listing part of the description:

pages NONE, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
☐ the language of publication of the international application (under Rule 48.3(b)).
☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in printed form.
☐ filed together with the international application in computer readable form.
☐ furnished subsequently to this Authority in written form.
☐ furnished subsequently to this Authority in computer readable form.
☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☒ The amendments have resulted in the cancellation of:

- ☒ the description, pages NONE
☒ the claims, Nos. NONE
☒ the drawings, sheets/fig NONE

5. ☒ This report has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

**Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/US99/14439

V. Reassessed statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**1. statement**

Novelty (N)

Claims	<u>1-16</u>	YES
Claims	<u>NONE</u>	NO

Inventive Step (IS)

Claims	<u>NONE</u>	YES
Claims	<u>1-16</u>	NO

Industrial Applicability (IA)

Claims	<u>1-16</u>	YES
Claims	<u>NONE</u>	NO

2. citations and explanations (Rule 70.7)

Claims 1-16 meet the criteria set out in PCT Article 33(2), because the prior art does not teach or fairly suggest a filter comprising a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region, wherein the thickness of the pleat tip region at a point spaced about one to four pleat leg thicknesses from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness.

Claims 1-16 lack an inventive step under PCT Article 33(3) as being obvious over either the European Patent (WO 94/22556; 11, 13, 16, 17, 19, 22 & 24 in Fig. 3; page 13, lines 9-25; page 14, lines 1-20) or the Japanese Patent (JP 404300612A; 1, 4, 5 & 7 in Fig. 1; Abstract).

Either the European reference or the Japanese reference discloses a filter comprising a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region, at least one of the pleats having a reformed pleat tip region and contacting pleat legs, and the pleats are free of bulbous pleat tip regions. Either the European reference or the Japanese reference discloses a method of making a filter comprising the steps of forming a plurality of pleats free of bulbous pleat tip regions and applying pressure to opposing outer surface of at least one pleat tip region. It would have been obvious to a person having ordinary skill in the art at the time the invention was made to modify the plurality of pleats free of bulbous pleat tip regions in order to reduce high differential pressure when filtering a fluid and to increase structural stability.

Claims 1-16 meet the criteria set out in PCT Article 33(4), because the claimed filter and method can be used to remove airborne boron contamination in the process of manufacturing semiconductors.

----- NEW CITATIONS -----

WO 94/22556 A, STOBBE, 13 October 1994, 11, 13, 16, 17, 19, 22 & (Continued on Supplemental Sheet.)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/US99/14439

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

<u>Application No. Patent No.</u>	<u>Publication Date (day/month/year)</u>	<u>Filing Date (day/month/year)</u>	<u>Priority date (valid claim) (day/month/year)</u>
US, A, 5,230,455	27 JULY 1993	23 APRIL 1992	NONE
US, A, 5,273,560	28 DECEMBER 1993	18 FEBRUARY 1992	NONE
US, A, 5,279,731	18 JANUARY 1994	09 SEPTEMBER 1991	NONE

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosureDate of non-written disclosure
(day/month/year)Date of written disclosure
referring to non-written disclosure
(day/month/year)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/US99/14439

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

Claims 13-16 are objected to under PCT Rule 66.2(a)(iii) as containing the following defect(s) in the form or contents thereof: improper multiple dependent claims (for example, the method claim should not depend on the apparatus claim and vice versa).

The drawings are objected to under PCT Rule 66.2(a)(iii) as containing the following defect(s) in the form or content thereof: Figure 1 should be labeled as --Prior Art--.

Supplemental Box

(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: Boxes I - VIII

Sheet 10

I. BASIS OF REPORT:

5. (Some) amendments are considered to go beyond the disclosure as filed:
NONE

V. 2. REASONED STATEMENTS - CITATIONS AND EXPLANATIONS (Continued):
24 in Fig. 3, page 13, lines 9-25, page 14, lines 1-20.

JP 404300612 A, WATANABE, 23 October 1992, 1, 4, 5 & 7 in Fig. 1, Abstract.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 440110/PALL	FOR FURTHER ACTION <small>see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.</small>	
International application No. PCT/US 99/ 14439	International filing date (day/month/year) 29/06/1999	(Earliest) Priority Date (day/month/year) 29/06/1998
Applicant PALL CORPORATION et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.



It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.



the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :



contained in the international application in written form.



filed together with the international application in computer readable form.



furnished subsequently to this Authority in written form.



furnished subsequently to this Authority in computer readable form.



the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.



the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,



the text is approved as submitted by the applicant.



the text has been established by this Authority to read as follows:

PLEATED FILTER AND A METHOD FOR MAKING THE SAME

5. With regard to the **abstract**,



the text is approved as submitted by the applicant.



the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.

3



as suggested by the applicant.



because the applicant failed to suggest a figure.



because this figure better characterizes the invention.



None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No

PC 99/14439

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B01D46/52

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 702 801 A (CHIEN JUNG-FU) 30 December 1997 (1997-12-30) column 2, line 11; figures 9,17 ---	1-11,13, 14,16
X	GB 2 225 543 A (ENVAIR) 6 June 1990 (1990-06-06) figure 2 ---	1,2, 8-11,13
X	EP 0 692 294 A (NIPPON DENSO CO) 17 January 1996 (1996-01-17) page 4, line 19-22; figure 2 -----	1-3,6-13

☐

Further documents are listed in the continuation of box C.

☒

Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

21 October 1999

Date of mailing of the international search report

29/10/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Polesak, H

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PC 99/14439

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5702801	A	30-12-1997	US	5558924 A	24-09-1996
			DE	69312763 D	11-09-1997
			DE	69312763 T	12-03-1998
			EP	0558205 A	01-09-1993
			ES	2109431 T	16-01-1998

GB 2225543	A	06-06-1990	NONE		

EP 0692294	A	17-01-1996	JP	8024546 A	30-01-1996
			JP	8038834 A	13-02-1996
			AT	171643 T	15-10-1998
			CN	1128174 A	07-08-1996
			DE	69505062 D	05-11-1998
			DE	69505062 T	12-05-1999
			US	5674302 A	07-10-1997
			ZA	9505211 A	14-02-1996

PATENT COOPERATION TREATY

WO 00/00270
PCT/US99/14439

PCT

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

From the INTERNATIONAL BUREAU

To:

BELZ, John, M.
Leydig, Voit & Mayer, Ltd.
Suite 300
700 Thirteenth Street, N.W.
Washington, DC 20005
ÉTATS-UNIS D'AMÉRIQUE

JAN 8 1999

Date of mailing (day/month/year) 06 January 2000 (06.01.00)		IMPORTANT NOTICE	
Applicant's or agent's file reference 440110/PALL			
International application No. PCT/US99/14439	International filing date (day/month/year) 29 June 1999 (29.06.99)	Priority date (day/month/year) 29 June 1998 (29.06.98)	
Applicant PALL CORPORATION et al			

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
AU,CN,EP,IL,JP,KP,KR,US

In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:

AE,AL,AM,AP,AT,AZ,BA,BB,BG,BR,BY,CA,CH,CU,CZ,DE,DK,EA,EE,ES,FI,GB,GD,GE,GH,GM,HR,
HU,ID,IN,IS,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MD,MG,MK,MN,MW,MX,NO,NZ,OA,PL,PT,RO,RU,
SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,UA,UG,UZ,VN,YU,ZA,ZW

The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
06 January 2000 (06.01.00) under No. WO 00/00270

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, a demand for international preliminary examination must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the national phase, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. (41-22) 740.14.35	Authorized officer J. Zahra Telephone No. (41-22) 338.83.38
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PCT COOPERATION TREATY

PCT

NOTIFICATION CONCERNING
SUBMISSION OR TRANSMITTAL
OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

From the INTERNATIONAL BUREAU

To:

BELZ, John, M.
Leydig, Voit & Mayer, Ltd.
Suite 300
700 Thirteenth Street, N.W.
Washington, DC 20005
ÉTATS-UNIS D'AMÉRIQUE

Date of mailing (day/month/year) 22 September 1999 (22.09.99)	
Applicant's or agent's file reference 440110/PALL	IMPORTANT NOTIFICATION
International application No. PCT/US99/14439	International filing date (day/month/year) 29 June 1999 (29.06.99)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 29 June 1998 (29.06.98)
Applicant PALL CORPORATION et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).
2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.
3. An asterisk(*) appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, the attention of the applicant is directed to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.
4. The letters "NR" appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, the attention of the applicant is directed to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

<u>Priority date</u>	<u>Priority application No.</u>	<u>Country or regional Office or PCT receiving Office</u>	<u>Date of receipt of priority document</u>
29 June 1998 (29.06.98)	60/091,042	US	20 Sept 1999 (20.09.99)

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer

Olivia RANAIVOJAONA

Telephone No. (41-22) 338.83.38

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference
(if desired) (12 characters maximum) 440110/PALL

Box No. I TITLE OF INVENTION

FILTERS AND METHODS OF MAKING FILTERS

Box No. II APPLICANT

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

PALL CORPORATION
2200 Northern Boulevard
East Hills, New York 11548-1209
US

☐ This person is also inventor.

Telephone No.

(516) 484-5400

Facsimile No.

(516) 484-5895

Teleprinter No.

State (that is, country) of nationality:

US

State (that is, country) of residence:

US

This person is applicant for the purposes of:

☐ all designated States☒ all designated States except the United States of America☐ the United States of America only☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

WELCH, Jr., Thomas C.
11 Lora Lane
Homer, New York 13077
US

This person is:

☐ applicant only☒ applicant and inventor☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

US

State (that is, country) of residence:

US

This person is applicant for the purposes of:

☐ all designated States☐ all designated States except the United States of America☒ the United States of America only☐ the States indicated in the Supplemental Box☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:

☒ agent☐ common representative

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

BELZ, John M.
Leydig, Voit & Mayer, Ltd.
Suite 300
700 Thirteenth Street, N.W.
Washington, D.C. 20005
US

Telephone No.

(202) 737-6770

Facsimile No.

(202) 737-6776

Teleprinter No.

☐ Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

VERSCHNEIDER, Joseph
42 North Church Street
Apartment 2N
Cortland, New York 13045
US

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

US

State (that is, country) of residence:

US

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

MILLER, John D.
511 Kline Road
Ithaca, New York 14850
US

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

US

State (that is, country) of residence:

US

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

State (that is, country) of residence:

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

State (that is, country) of residence:

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

The following designations are hereunder under Rule 4.9(a) (mark the applicable check-box)

one must be marked):

Regional Patent

- ☒ AP ARIPO Patent: GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, UG Uganda, ZW Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☒ EA Eurasian Patent: AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakhstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☒ EP European Patent: AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, CY Cyprus, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☒ OA OAPI Patent: BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT (if other kind of protection or treatment desired, specify on dotted line)

National Patent (if other kind of protection or treatment desired, specify on dotted line):

- | | |
|--|--|
| <input checked="" type="checkbox"/> AE United Arab Emirates | <input checked="" type="checkbox"/> LR Liberia |
| <input checked="" type="checkbox"/> AL Albania | <input checked="" type="checkbox"/> LS Lesotho |
| <input checked="" type="checkbox"/> AM Armenia | <input checked="" type="checkbox"/> LT Lithuania |
| <input checked="" type="checkbox"/> AT Austria | <input checked="" type="checkbox"/> LU Luxembourg |
| <input checked="" type="checkbox"/> AU Australia | <input checked="" type="checkbox"/> LV Latvia |
| <input checked="" type="checkbox"/> AZ Azerbaijan | <input checked="" type="checkbox"/> MD Republic of Moldova |
| <input checked="" type="checkbox"/> BA Bosnia and Herzegovina | <input checked="" type="checkbox"/> MG Madagascar |
| <input checked="" type="checkbox"/> BB Barbados | <input checked="" type="checkbox"/> MK The former Yugoslav Republic of Macedonia |
| <input checked="" type="checkbox"/> BG Bulgaria | |
| <input checked="" type="checkbox"/> BR Brazil | <input checked="" type="checkbox"/> MN Mongolia |
| <input checked="" type="checkbox"/> BY Belarus | <input checked="" type="checkbox"/> MW Malawi |
| <input checked="" type="checkbox"/> CA Canada | <input checked="" type="checkbox"/> MX Mexico |
| <input checked="" type="checkbox"/> CH and LI Switzerland and Liechtenstein | <input checked="" type="checkbox"/> NO Norway |
| <input checked="" type="checkbox"/> CN China | <input checked="" type="checkbox"/> NZ New Zealand |
| <input checked="" type="checkbox"/> CU Cuba | <input checked="" type="checkbox"/> PL Poland |
| <input checked="" type="checkbox"/> CZ Czech Republic | <input checked="" type="checkbox"/> PT Portugal |
| <input checked="" type="checkbox"/> DE Germany | <input checked="" type="checkbox"/> RO Romania |
| <input checked="" type="checkbox"/> DK Denmark | <input checked="" type="checkbox"/> RU Russian Federation |
| <input checked="" type="checkbox"/> EE Estonia | <input checked="" type="checkbox"/> SD Sudan |
| <input checked="" type="checkbox"/> ES Spain | <input checked="" type="checkbox"/> SE Sweden |
| <input checked="" type="checkbox"/> FI Finland | <input checked="" type="checkbox"/> SG Singapore |
| <input checked="" type="checkbox"/> GB United Kingdom | <input checked="" type="checkbox"/> SI Slovenia |
| <input checked="" type="checkbox"/> GD Grenada | <input checked="" type="checkbox"/> SK Slovakia |
| <input checked="" type="checkbox"/> GE Georgia | <input checked="" type="checkbox"/> SL Sierra Leone |
| <input checked="" type="checkbox"/> GH Ghana | <input checked="" type="checkbox"/> TJ Tajikistan |
| <input checked="" type="checkbox"/> GM Gambia | <input checked="" type="checkbox"/> TM Turkmenistan |
| <input checked="" type="checkbox"/> HR Croatia | <input checked="" type="checkbox"/> TR Turkey |
| <input checked="" type="checkbox"/> HU Hungary | <input checked="" type="checkbox"/> TT Trinidad and Tobago |
| <input checked="" type="checkbox"/> ID Indonesia | <input checked="" type="checkbox"/> UA Ukraine |
| <input checked="" type="checkbox"/> IL Israel | <input checked="" type="checkbox"/> UG Uganda |
| <input checked="" type="checkbox"/> IN India | <input checked="" type="checkbox"/> US United States of America |
| <input checked="" type="checkbox"/> IS Iceland | |
| <input checked="" type="checkbox"/> JP Japan | <input checked="" type="checkbox"/> UZ Uzbekistan |
| <input checked="" type="checkbox"/> KE Kenya | <input checked="" type="checkbox"/> VN Viet Nam |
| <input checked="" type="checkbox"/> KG Kyrgyzstan | <input checked="" type="checkbox"/> YU Yugoslavia |
| <input checked="" type="checkbox"/> KP Democratic People's Republic of Korea | <input checked="" type="checkbox"/> ZA South Africa |
| | <input checked="" type="checkbox"/> ZW Zimbabwe |

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

- ☐
- ☐

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. (Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)

Box No. VI PRIORITY CLAIM		<input type="checkbox"/> Further priority claims indicated in the Supplemental B x.		
Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is:		
		national application: country	regional application: regional Office	international application: receiving Office
item (1) 29.06.98 29 June 1998	60/091,042	US		
item (2)				
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) (only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office) identified above as item(s): (1)

* Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) (if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used): ISA / EP	Request to use results of earlier search; reference to that search (if an earlier search has been carried out by or requested from the International Searching Authority): Date (day/month/year) Number Country (or regional Office)
---	--

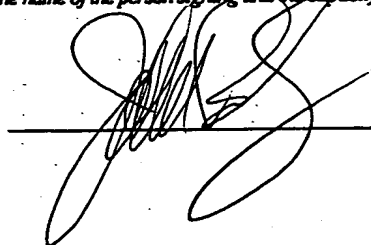
Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following number of sheets: request : 4 description (excluding sequence-listing part) : 30 claims : 2 abstract : 1 drawings : 11 sequence listing part of description : Total number of sheets : 48	This international application is accompanied by the item(s) marked below: 1. <input checked="" type="checkbox"/> fee calculation sheet duplicate copy enclosed 2. <input type="checkbox"/> separate signed power of attorney 3. <input checked="" type="checkbox"/> copy of general power of attorney; reference number, if any: Miller, Welch 4. <input type="checkbox"/> statement explaining lack of signature Weiner 5. <input type="checkbox"/> priority document(s) identified in Box No. VI as item(s): 6. <input type="checkbox"/> translation of international application into (language): 7. <input type="checkbox"/> separate indications concerning deposited microorganism or other biological material 8. <input type="checkbox"/> nucleotide and/or amino acid sequence listing in computer readable form 9. <input checked="" type="checkbox"/> other (specify): Transmittal Letter to RO/US
--	---

Figure of the drawings which should accompany the abstract: FIG. 3	Language of filing of the international application: English
--	--

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).



John M. BELZ,
Agent for the Applicant(s)

For receiving Office use only		2. Drawings: <input type="checkbox"/> received: <input type="checkbox"/> not received:
1. Date of actual receipt of the purported international application:		
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:		
4. Date of timely receipt of the required corrections under PCT Article 1(2):		
5. International Searching Authority (if two or more are competent): ISA /	6. <input type="checkbox"/> Transmittal of search copy delayed until search fee is paid.	

For International Bureau use only
Date of receipt of the record copy by the International Bureau:

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To: JOHN M. BELZ
LEYDIG, VOIT & MAYER, LTD.
700 THIRTEENTH STREET, N.W.
SUITE 300
WASHINGTON, DC 20005

PCT

WRITTEN OPINION

(PCT Rule 66)

JUL 12 2000

Date of Mailing
(day/month/year) **07 JUL 2000**

Applicant's or agent's file reference
440110/PALL

REPLY DUE within **TWO** months
from the above date of mailing

International application No.
PCT/US99/14439

International filing date (day/month/year)
29 JUNE 1999

Priority date (day/month/year)
29 JUNE 1998

International Patent Classification (IPC) or both national classification and IPC
IPC(7): B01D 46/10, 46/24 and US Cl.: 55/497, 498, 499, 500, 521, DIG 5

Applicant
PALL CORPORATION

1. This written opinion is the first (first, etc.) drawn by this International Preliminary Examining Authority.

2. This opinion contains indications relating to the following items:

- I ☒ Basis of the opinion
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step or industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☒ Certain documents cited
- VII ☒ Certain defects in the international application
- VIII ☐ Certain observations on the international application

3. The applicant is hereby invited to reply to this opinion.

When? See the time limit indicated above. ~~The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).~~

How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

Also For an additional opportunity to submit amendments, see Rule 66.4.
For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4 *bis*.
For an informal communication with the examiner, see Rule 66.6.

If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: **29 OCTOBER 2000**

Name and mailing address of the IPEA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

David Simmons
DAVID SIMMONS

Telephone No. (703) 308-0661

PCT

WRITTEN OPINION

International application No.

PCT/US99/14439

I. Basis of the opinion

1. With regard to the elements of the international application:*

☒ the international application as originally filed

☒ the description:

pages 1-30 , as originally filed
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

☒ the claims:

pages 31-32 , as originally filed
pages NONE , as amended (together with any statement) under Article 19
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

☒ the drawings:

pages 1-11 , as originally filed
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

☒ the sequence listing part of the description:

pages NONE , as originally filed
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language _____ which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the written opinion was drawn on the basis of the sequence listing:

- ☐ contained in the international application in printed form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☒ The amendments have resulted in the cancellation of:

- ☒ the description, pages NONE
- ☒ the claims, Nos. NONE
- ☒ the drawings, sheets/fig. NONE

5. ☐ This opinion has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed".*

WRITTEN OPINION

International application No.

PCT/US99/14439

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. statement

Novelty (N)	Claims <u>1-16</u>	YES
	Claims <u>NONE</u>	NO
Inventive Step (IS)	Claims <u>NONE</u>	YES
	Claims <u>1-16</u>	NO
Industrial Applicability (IA)	Claims <u>1-16</u>	YES
	Claims <u>NONE</u>	NO

2. citations and explanations

Claims 1-16 meet the criteria set out in PCT Article 33(2), because the prior art does not teach or fairly suggest a filter comprising a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region, wherein the thickness of the pleat tip region at a point spaced about one to four pleat leg thicknesses from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness.

Claims 1-16 lack an inventive step under PCT Article 33(3) as being obvious over either the European Patent (WO 94/22556; 11, 13, 16, 17, 19, 22 & 24 in Fig. 3; page 13, lines 9-25; page 14, lines 1-20) or the Japanese Patent (JP 404300612A; 1, 4, 5 & 7 in Fig. 1; Abstract).

Either the European reference or the Japanese reference discloses a filter comprising a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region, at least one of the pleats having a reformed pleat tip region and contacting pleat legs, and the pleats are free of bulbous pleat tip regions. Either the European reference or the Japanese reference discloses a method of making a filter comprising the steps of forming a plurality of pleats free of bulbous pleat tip regions and applying pressure to opposing outer surface of at least one pleat tip region. It would have been obvious to a person having ordinary skill in the art at the time the invention was made to modify the plurality of pleats free of bulbous pleat tip regions in order to reduce high differential pressure when filtering a fluid and to increase structural stability.

Claims 1-16 meet the criteria set out in PCT Article 33(4), because the claimed filter and method can be used to remove airborne boron contamination in the process of manufacturing semiconductors.

————— NEW CITATIONS —————

WO 94/22556 A, STOBBE, 13 October 1994, 11, 13, 16, 17, 19, 22 & (Continued on Supplemental Sheet.)

WRITTEN OPINION

International application No.

PCT/US99/14439

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

<u>Applicati n N . Patent No.</u>	<u>Publication Date (day/month/year)</u>	<u>Filing Date (day/month/year)</u>	<u>Pri rity date (valid claim) (day/month/year)</u>
US, A, 5,230,455	27 JULY 1993	23 APRIL 1992	NONE
US, A, 5,273,560	28 DECEMBER 1993	18 FEBRUARY 1992	NONE
US, A, 5,279,731	18 JANUARY 1994	09 SEPTEMBER 1991	NONE

2. Non-written disclosures (Rule 70.9)

<u>Kind of non-written disclosure</u>	<u>Date of non-written disclosure (day/month/year)</u>	<u>Date of written disclosure referring to non-written disclosure (day/month/year)</u>
---------------------------------------	--	--

WRITTEN OPINION

International application No.

PCT/US99/14439

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

Claims 13-16 are objected to under PCT Rule 66.2(a)(iii) as containing the following defect(s) in the form or contents thereof: improper multiple dependent claims (for example the method claim should not depend on the apparatus claim and vice versa).

The drawings are objected to under PCT Rule 66.2(a)(iii) as containing the following defect(s) in the form or content thereof: Figure 1 should be labeled as --Prior Art--.

Supplemental B x

(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: Boxes I - VIII

Sheet 10

TIME LIMIT:

The time limit set for response to a Written Opinion may not be extended. 37 CFR 1.484(d). Any response received after the expiration of the time limit set in the Written Opinion will not be considered in preparing the International Preliminary Examination Report.

V. 2. REASONED STATEMENTS - CITATIONS AND EXPLANATIONS (Continued):

24 in Fig. 3, page 13, lines 9-25, page 14, lines 1-20.

JP 404300612 A, WATANABE, 23 October 1992, 1, 4, 5 & 7 in Fig. 1, Abstract.

ENT COOPERATION TREATY

PCT

INFORMATION CONCERNING ELECTED
OFFICES NOTIFIED OF THEIR ELECTION

(PCT Rule 61.3)

From the INTERNATIONAL BUREAU

To:

BELZ, John, M.
Leydig, Voit & Mayer, Ltd.
Suite 300
700 Thirteenth Street, N.W.
Washington, DC 20005
ETATS-UNIS D'AMERIQUE

Date of mailing (day/month/year) 11 April 2000 (11.04.00)		IMPORTANT INFORMATION	
Applicant's or agent's file reference 440110/PALL			
International application No. PCT/US99/14439	International filing date (day/month/year) 29 June 1999 (29.06.99)	Priority date (day/month/year) 29 June 1998 (29.06.98)	
Applicant PALL CORPORATION et al			

1. The applicant is hereby informed that the International Bureau has, according to Article 31(7), notified each of the following Offices of its election:

AP : GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW

EP : AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE

National : AU, BG, BR, CA, CN, CZ, DE, IL, JP, KP, KR, MN, NO, NZ, PL, RO, RU, SE, SK, US

2. The following Offices have waived the requirement for the notification of their election; the notification will be sent to them by the International Bureau only upon their request:

EA : AM, AZ, BY, KG, KZ, MD, RU, TJ, TM

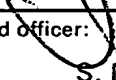
OA : BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG

National : AE, AL, AM, AT, AZ, BA, BB, BY, CH, CU, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU,
ID, IN, IS, KE, KG, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MW, MX, PT, SD, SG, SI, SL, TJ,
TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW

3. The applicant is reminded that he must enter the "national phase" before the expiration of 30 months from the priority date before each of the Offices listed above. This must be done by paying the national fee(s) and furnishing, if prescribed, a translation of the international application (Article 39(1)(a)), as well as, where applicable, by furnishing a translation of any annexes of the international preliminary examination report (Article 36(3)(b) and Rule 74.1).

Some offices have fixed time limits expiring later than the above-mentioned time limit. For detailed information about the applicable time limits and the acts to be performed upon entry into the national phase before a particular Office, see Volume II of the PCT Applicant's Guide.

The entry into the European regional phase is postponed until 31 months from the priority date for all States designated for the purposes of obtaining a European patent.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. (41-22) 740.14.35	Authorized officer:  S. Mafla Telephone No. (41-22) 338.83.38
--	--

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

PCT

To:

JOHN M. BELZ
LEYDIG, VOIT & MAYER, LTD.
700 THIRTEENTH STREET, N.W.
SUITE 300
WASHINGTON DC 20005

24

NOTIFICATION OF RECEIPT OF DEMAND BY COMPETENT INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

(PCT Rule 59.3(e) and 61.1(b), first sentence
and Administrative Instructions, Section 601(a))

Date of mailing
(day/month/year)

21 MAR 2000

Applicant's or agent's file reference
440110/PALL

IMPORTANT NOTIFICATION

International application No.
PCT/US99/14439

International filing date (day/month/year)
29 JUN 99

Priority date (day/month/year)
29 JUN 98

Applicant

PALL CORPORATION

1. The applicant is hereby **notified** that this International Preliminary Examining Authority considers the following date as the date of receipt of the demand for international preliminary examination of the international application:

21 MAR 2000

2. That date of receipt is:

- ☒ the actual date of receipt of the demand by this Authority (Rule 61.1(b)).
- ☐ the actual date of receipt of the demand on behalf of this Authority (Rule 59.3(e)).
- ☐ the date on which this Authority has, in response to the invitation to correct defects in the demand (Form PCT/IPEA/404), received the required corrections.

3. ☐ **ATTENTION:** That date of receipt is **AFTER** the expiration of 19 months from the priority date. Consequently, the election(s) made in the demand does (do) not have the effect of postponing the entry into the national phase until 30 months from the priority date (or later in some Offices) (Article 39(1)). Therefore, the acts for entry into the national phase must be performed within 20 months from the priority date (or later in some Offices) (Article 22). For details, see the *PCT Applicant's Guide*, Volume II.

- ☐ (If applicable) This notification confirms the information given by telephone, facsimile transmission or in person on:

4. Only where paragraph 3 applies, a copy of this notification has been sent to the International Bureau.

Name and mailing address of the IPEA/US
Assistant Commissioner for Patents
Box PCT
Washington, D.C. 20231
Facsimile No.

Attn: IPEA/US

Authorized officer

Telephone No.

Laurence Russell
703 306-5829

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ US

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:

The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States (except where otherwise indicated).

For International Preliminary Examining Authority use only		
Identification of IPEA		Date of receipt of DEMAND
Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION		Applicant's or agent's file reference 440110/PALL
International application No. PCT/US99/14439	International filing date (day/month/year) 29 June 1999 (29.06.99)	(Earliest) Priority date (day/month/year) 29 June 1998 (29.06.98)
Title of invention FILTERS AND METHODS OF MAKING FILTERS		
Box No. II APPLICANT(S)		
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.) PALL CORPORATION 2200 Northern Boulevard East Hills, New York 11548-1209 US		Telephone No.: (516) 484-5400 Facsimile No.: (516) 484-5895 Teleprinter No.:
State (that is, country) of nationality: US		State (that is, country) of residence: US
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.) WELCH, Thomas C. 11 Lora Lane. Homer, New York 13077 US		
State (that is, country) of nationality: US		State (that is, country) of residence: US
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.) VERSCHNEIDER, Joseph Apartment 2N 42 North Church Street Cortland, New York 13045		
State (that is, country) of nationality:		State (that is, country) of residence:
<input type="checkbox"/> Further applicants are indicated on a continuation sheet.		

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

MILLER, John D.
511 Kline Road
Ithaca, New York 14850
US

State (that is, country) of nationality:

US

State (that is, country) of residence:

US

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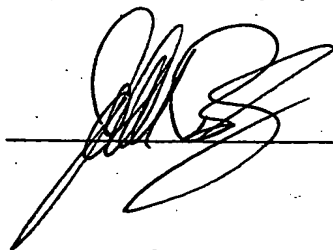
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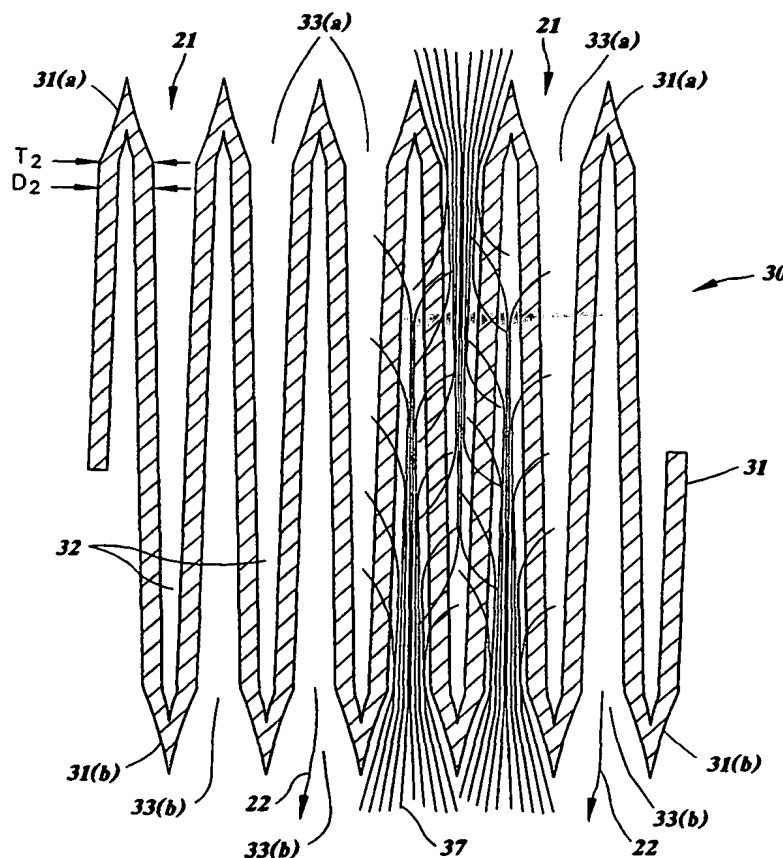
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(54) Title: PLEATED FILTER AND A METHOD FOR MAKING THE SAME

(57) Abstract

Filters having non-bulbous pleat tip regions are disclosed along with processes and apparatus for making filters having non-bulbous pleat tip regions.



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PLEATED FILTER AND A METHOD FOR MAKING THE SAME

This application claims the priority of U.S. Provisional Patent Application No. 60/091,042, filed June 29, 1998, which is incorporated by reference in its entirety.

Background of the Invention

Fluid filtration, e.g., gas filtration or liquid filtration, is important in a wide variety of industrial processes, including in the manufacture of electronic devices. Air filtration, for example, is very important in manufacturing semiconductors. Semiconductors are manufactured in ultra-clean manufacturing facilities called "clean rooms". Unlike ordinary rooms, clean rooms are substantially free of particulate contaminants. Typical clean rooms can have less than 100 particles per cubic foot. If the air in a clean room is not substantially free of particulate contaminants, the particulate contaminants in the air can decrease semiconductor yields. For example, contaminants in the air of a clean room can deposit on an unprotected circuit of a semiconductor potentially short-circuiting and damaging the semiconductor. Damaged semiconductors are usually reworked or discarded as scrap.

Conventional air filters for clean rooms use filter media made from glass fibers. While glass fiber filter media can be capable of filtering particulate contaminants from an incoming air stream, glass fiber filter media itself can produce contaminants which can lower semiconductor yields. For example, conventional glass fiber filter media contains borosilicate glass, which can produce boron-containing contaminants. Fluorine gas (e.g., released from etching processes) and water in the air of a clean room can combine to react with the borosilicate glass fibers in the filter media and produce airborne, boron-containing contaminants such as silicon boride. These airborne, boron-containing contaminants can decrease semiconductor yields by settling on the semiconductors during processing. Silicon boride contaminants, for example, can degrade the electrical properties of semiconductors

and consequently decrease semiconductor yields. Since the air in a clean room must be filtered, most semiconductor process engineers simply accept airborne boron contamination as inevitable and employ additional process steps to compensate for the contamination. For instance, a buffered HF (hydrogen fluoride) clean-and-etch step can be added to remove some of the boron contamination from the surface of a semiconductor.

Filtering the clean room air with a filter medium substantially free of boron may reduce the amount of boron contaminants in a clean room. However, conventional filters incorporating substantially boron-free filter media, such as polymeric filter media, may not be advantageous. A filter medium is typically pleated in order to increase the filter surface area for a predefined envelope (e.g., a space defined by a housing or frame). When a polymeric filter medium (e.g., a filter medium formed from a polymeric material such as polymeric fibers) is pleated, the medium can have a tendency to "spring back" in the pleat tip region, resulting in a pleat tip region with a conventional bulbous shape. A pleated filter medium having conventional bulbous-shaped pleat tip regions can disadvantageously have a low number of pleats per unit of length, exhibit high differential pressure when filtering a fluid and/or have a diminished structural stability. Further, due to the "spring back" properties of many polymeric filter media, such media can be difficult to pleat.

Figure 1 shows a portion of a filter element 20, which includes a pleated filter medium 11 having a plurality of upstream conventional bulbous-shaped pleat tip regions 11(a) and downstream conventional bulbous-shaped pleat tip regions 11(b). A contaminated fluid stream 21 flowing towards the upstream spaces 12(a) between the pleats of the pleated filter medium 11 may be impeded by the upstream conventional bulbous-shaped pleat tip regions 11(a). The spaces 12(a) between the adjacent upstream conventional bulbous-shaped pleat tip regions 11(a) are relatively narrow and may bottleneck the flow of the contaminated fluid stream 21 into the pleated filter medium 11. Eventually, the contaminated fluid stream

21 passes through the pleated filter medium 11 forming a purified fluid stream 22. The purified fluid stream 22 can then flow in the downstream spaces 12(b) between the downstream pleat tip regions 11(b) of the pleated filter medium 11, before exiting the pleated filter medium 11. As the purified fluid stream 22 flows downstream, the downstream conventional bulbous-shaped pleat tip regions 11(b) can impede the flow of the purified fluid stream 22 out of the pleated filter medium 11. The spaces 12(b) between the adjacent downstream conventional bulbous-shaped pleat tip regions 11(b) are relatively narrow, and may bottleneck the flow of the purified fluid stream 22 out the pleated filter medium 11. The fluid stream lines 17 through the filter element show the bottlenecks at the upstream and downstream pleat tip regions. These bottlenecks greatly increase the pressure drop across the filter element. Consequently, greater upstream pressure may be required to force the contaminated fluid stream 21 past the upstream conventional bulbous-shaped pleat tip regions 11(a) and the purified fluid stream 22 past the downstream conventional bulbous-shaped pleat tip regions 11(b). Unfortunately, greater upstream fluid pressures require greater energy to compress the contaminated fluid stream.

Summary of the Invention

One aspect of the invention is directed to a filter element, filter pack or filter composite comprising a pleated filter medium including pleats having a pleat tip region with a predetermined shape.

Another aspect of the invention is directed to a filter comprising a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region. A thickness of the pleat tip region at a point spaced about one to four pleat leg thicknesses from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness.

Another aspect of the invention is directed to a filter comprising a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region. A thickness of the pleat tip region at a point spaced about one to four pleat leg thicknesses from the end of the pleat is less than or equal to a distance between corresponding points on opposing outer surfaces of the pleat legs.

Another aspect of the invention is directed to a filter comprising a pleated structure having a plurality of pleats and more than one layer. At least one of the pleats having a reformed pleat tip region.

Another aspect of the invention is directed to a filter comprising a pleated structure having a plurality of pleats and a pair of pleat legs, at least one of the pleats having a reformed pleat tip region and contacting pleat legs.

Another aspect of the invention is directed to a filter comprising a plurality of pleats, at least one pleat including a pleat tip region having contacting inner surfaces.

Another aspect of the invention is directed to a filter comprising a pleated porous sheet having a polymeric material and a plurality of pleats. At least one pleat includes a pair of pleat legs and a pleat tip region, the pleat tip region including a pre-scored region.

Another aspect of the invention is directed to a method of making a filter comprising: forming a plurality of pleats having pleat tip regions; and applying pressure to opposing outer surfaces of at least one pleat tip region.

Another aspect of the invention is directed to a method of making a filter comprising: forming a plurality of pleats free of bulbous pleat tip regions.

Another aspect of the invention is directed to a method of making a filter comprising: forming a plurality of pleats wherein a thickness of each pleat tip region at eight points spaced about 1 to about 4 pleat leg thicknesses from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness.

Another aspect of the invention is directed to a method of making a filter comprising: forming a plurality of pleats, wherein a thickness of the pleat tip region at eight points spaced about one to about four pleat leg thicknesses from the end of the pleat tip region is less than or equal to a distance between corresponding points on opposing outer surfaces of the pleat leg.

Another aspect of the invention is directed to a method of making a filter comprising: scoring a porous sheet including a polymeric material; and pleating the porous sheet.

Another aspect of the invention is directed to an apparatus comprising one or more dies arranged to reform a pleat tip region of a pleat.

While the filtration of clean room air has been discussed in detail, embodiments of the invention are not limited to filtering clean room air. For example, embodiments of the invention can relate to cabin air filters, which can be used to filter the air of an aircraft cabin, as well as flat and cylindrical pleated filters for liquid service. For example, embodiments of the invention can also be used to filter liquids such as fuel. Further, embodiments of the invention relate to pleated filters useful in dead end filtration, for example, where process fluid flows radially through a cylindrical pleated filter pack, or in cross flow filtration, for example, where process fluid flows axially along a cylindrical pleated filter pack.

Embodiments of the invention can provide for a number of advantages. For example, embodiments of the invention can provide for reduced differential pressure across the filter or filter medium, improved filtration properties, improved flow properties through or along the filter, improved structural properties and/or reduced contaminant production. The systems and methods according to embodiments of the invention can provide for efficient and low cost manufacture of filters and filter media.

Brief Description of the Drawings

Figure 1 illustrates a side view of a filter element including a filter medium having conventional bulbous-shaped pleat tip regions.

Figures 2(a) and 2(b) illustrate cross-sections of pleats.

5 Figure 3 illustrates a side view of a filter element of an embodiment of the invention.

Figures 4(a)-4(c) show cross-sectional views of pleats.

Figures 5-8 show methods and systems.

Figures 9(a)-9(f) show cross-sectional views of pre-scored sheets and pleats.

10

Detailed Description

Pleated filter elements embodying the invention may be configured in a wide variety of ways. For example, the filter element may be configured as a parallelepiped or a cylinder. The pleats of the filter element may include generally parallel or non-parallel legs which are straight or curved and which contact one another or are spaced from one another. United States Patents
15 No. 5,098,767; No. 5,252,207; and No. 5,543,047 and United States Patent Application No. 60/099,663 disclose many of these features and are incorporated herein by reference.

In some pleated filter elements embodying the invention, one or more, and preferably all, of the pleats include a pair of pleat legs and a pleat tip region having a predetermined, non-bulbous shape, e.g., a tapered, squared, or rounded shape. A pleat tip region can include any
20 suitable portion near the crest and/or root of a pleat including an apex of the pleat. For example, a pleat tip region may extend any suitable length along a pleat in the vicinity of an apex of the pleat. In the pleat tip regions, the thickness of the pleat tip region at a point in the vicinity of about one to about four pleat leg thicknesses from the end of the pleat tip region can be less than about twice the thickness of a corresponding pleat leg. Other embodiments can be
25 directed to a filter including a pleated porous sheet having a plurality of pleats, at least one

pleat comprising a pair of pleat legs and a pleat tip region. A thickness of the sheet at the pleat tip region is less than one pleat leg thickness, and the pleat legs may contact one another. The term "sheet" includes any suitable structure having one or more layers. For example, a "sheet" can include a filter medium having one, two, three, or more layers. In
5 another example, a "sheet" can include a filter composite having several layers in addition to a filter medium, including one or more drainage layers and/or a cushioning layer.

Each of the Figures including Figs. 2(a) and 2(b) show pleats, and each pleat includes two pleat legs joined at a pleat tip region including an apex of the pleat. Each leg is illustrated as a single layer structure but it is representative of one or more layers and is correspondingly
10 described as a "filter medium" or a "filter composite". Thus, this aspect of the drawings is merely representational. As explained above, a filter medium can have one, two, three, or more layers, and a filter composite can comprise several layers in addition to a filter medium, including one or more drainage layers and/or a cushioning layer. Embodiments of the invention are particularly advantageous for a filter medium or a filter composite having a porous
15 polymeric fibrous medium, such as a polymeric fibrous depth filter medium. Such a medium is very springy and resists the formation of a sharp fold in conventional corrugators. Consequently, conventional filters having fibrous polymeric media have conventional bulbous pleat tip regions, as shown in Figure 2(a).

The pleat shown in Figure 2(a) includes two pleat legs 8(a), 8(b) and a pleat tip region
20 11(c) with a conventional bulbous shape. The conventional bulbous-shaped pleat tip region 11(c) can naturally result from folding a sheet of filter medium or filter composite upon itself. The thickness of the conventional bulbous-shaped pleat tip region 11(c) is greater than the thickness of other portions of the pleat. For example, the thickness T of the pleat tip region is greater than a distance D_1 between corresponding points on opposing outer surfaces of the
25 pleat legs 8(a), 8(b). Further, the thickness T of the pleat tip region in the vicinity from about

one to about four pleat leg thicknesses from the end of the pleat is greater than twice the thickness t_2 of a pleat leg. Consequently, the packing density (e.g., the number of pleats per inch) of similarly shaped adjacent pleats is limited by the thickness the pleat tip regions of the pleats. Also, greater upstream fluid pressures are required to filter a contaminated fluid stream with a pleated filter medium or composite having conventional bulbous-shaped pleat tip regions. As explained previously, the narrow flow passages between adjacent conventional bulbous-shaped pleat tip regions may bottleneck the flow of the contaminated and purified fluid streams into and out of the pleats of the filter medium or composite. Further, the structural stability of the pleat could be improved.

In contrast, Figure 2(b) illustrates a pleat, for example, a pleat of filter medium or filter composite according to an embodiment of the invention. Figure 2(b) shows a pleat of a polymeric medium, such as a fibrous polymeric medium, having a non-bulbous shaped pleat tip region 11(d) and two pleat legs 9(a), 9(b) disposed generally parallel to one another. The pleat tip region 11(d) may be tapered and/or may have improved structural stability. The thickness of the pleat tip region 11(d) is less than the thickness of other portions of the pleat. For example, the thickness of the pleat tip region, T_1 , is less than a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 9(a), 9(b). Further, the thickness of the pleat tip region at a point in the vicinity of about one to about four pleat leg thicknesses t_2 , preferably about one to two pleat leg thicknesses t_2 , and more preferably about one pleat leg thickness t_2 , from the end of the pleat tip region is less than or equal to about twice the thickness t_2 of a corresponding pleat leg. Because the pleat shown in Figure 2(b) has a narrowly confined pleat tip region, the proximity of similarly shaped adjacent pleats is not limited by thickness of the pleat tip regions. Consequently, the pleats of the pleated filter medium or composite having non-bulbous shaped pleat tip regions can be packed closer

together than a corresponding medium or composite having conventional bulbous-shaped pleat tip regions.

Closely packed pleats or high packing efficiencies can be advantageous. In embodiments of the invention, the number of pleats per length may be increased by up to 80% to 100% or more. For example, a pleated filter medium or filter composite having conventional bulbous-shaped pleat tip regions and an average pleat leg thickness of about 30/1000 inch may have a maximum of 6 or 7 pleats per inch. In contrast, a pleated filter medium or composite having the same pleat leg thickness, but with pleat tip regions in accordance with embodiments of the invention, can have between about 10 and 12 pleats per inch. Advantageously, a filter element including a pleated filter medium or filter composite having closely packed pleats can have improved filtration properties, because the effective filtration area for a predetermined envelope (e.g., a space defined by a housing) can be increased.

The advantage of having closely packed pleats is even more evident when such pleats are used in conjunction with cylindrical pleated filters where the number of pleats is typically inversely proportional to two times the thickness of the pleated material (e.g., the thickness corresponding to a single pleat of material). By providing (e.g., by reforming) a pleated sheet with pleat tip regions with a thickness of less than about two times the thickness at a pleat leg, the number of pleats and thus the effective filter area for a given envelope can be increased proportionally. For instance, in embodiments of the invention, increases in the number of pleats and/or effective filter area can be greater than or equal to about 15% in comparison with conventional pleated structures.

Embodiments of the invention can provide for other advantages. A pleated filter medium or filter composite without bulbous shaped pleat tip regions can provide improved flow properties through or along the filter. For example, eliminating the bulbous shaped pleat

tip regions from a cross flow filter embodying the invention eliminates large channels through which the process fluid would otherwise preferentially flow. This provides more even contact between the process fluid and the entire filter medium and enhances residence time within the filter. On the permeate side of the filter eliminating the bulbous shaped pleat tip regions eliminates preferential flow of permeate into these bulbous-shaped channels, providing a more even flow through the filter medium.

A pleated filter medium or filter composite without bulbous shaped pleat tip regions can also provide for lower differential pressure across the medium or composite. For example, a pleated filter medium or filter composite having non-bulbous shaped pleat tip regions can have wider and/or more uniform fluid flow passages between adjacent pleats than a pleated filter medium or filter composite having conventional bulbous-shaped pleat tip regions. These wider and/or more uniform flow passages permit fluid streams to flow into and past the pleated filter medium or composite with greater ease and with less upstream fluid pressure. This advantage can be more clearly illustrated with reference to Figure 3.

Figure 3 shows a portion of a pleated filter element 30 including a pleated filter medium or filter composite 31. The pleated filter medium or filter composite 31 includes a plurality of upstream and downstream pleat tip regions 31(a), 31(b) embodying the invention. Each of the pleat tip regions 31(a), 31(b) may include a maximum thickness T_2 which can be less than or equal to a minimum distance D_2 between opposing outer surfaces of corresponding pleat legs. Further, the thickness of each pleat tip region at a point in the vicinity of about one to about four pleat leg thicknesses, preferably about one to two pleat leg thicknesses, and more preferably about one pleat leg thickness from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness. Because the upstream pleat tip regions 31(a) of the pleated filter medium 31 are substantially free of a conventional bulbous-shape, a contaminated fluid stream 21 can flow relatively unimpeded into the

upstream spaces 33(a) between adjacent upstream pleat tip regions 31(a), and into the spaces 32 between the pleats of the pleated filter medium 31. The contaminated fluid stream 21 then passes through the pleated filter medium 31 forming a purified fluid stream 22. The purified fluid stream 22 can then flow downstream out of the pleated filter medium 31 relatively
5 unimpeded in the downstream spaces 33(b) between adjacent downstream pleat tip regions 31(b). Less upstream pressure and energy are required to filter a contaminated fluid with the filter element 30 shown in Figure 3 than the filter element 20 shown in Figure 1. This is because the filter medium 31 in Figure 3 does not have conventional bulbous-shaped pleat tip regions which impede the flow of the contaminated and purified fluid streams 21, 22 between
10 the pleat tip regions 31(a), 31(b). As illustrated by the fluid stream lines 37, the flow of the contaminated fluid stream 21 and the purified fluid stream 22 is not substantially impeded in the spaces between the pleat tip regions 31(a), 31(b).

Embodiments of the invention can have pleat tip regions with any suitable shape. For example, the inner surfaces of the pleat tip regions may have any suitable shape, including a
15 flat, pointed, tapered, squared, rounded, triangular or irregular shape. The outer surfaces of the pleat tip regions may also have any suitable shape, such as a tapered, pointed, flat, rounded, oblong, squared, triangular, or irregular shape. Regardless of the particular pleat tip region shape, the thickness of a pleat tip region is preferably less than about two times the thickness of a pleat leg and/or is less than a distance between corresponding points on
20 opposing outer surfaces of the pleat legs.

If the shape of the outer and/or inner surface of the pleat tip region is tapered, the taper may be either gradual or intermittent (e.g., stepped). Tapered pleat tip regions advantageously do not substantially impede the flow of an approaching or passing fluid stream. As explained previously, adjusting the shape of the pleat tip regions of a pleated

filter medium or composite can reduce the differential pressure across the medium or composite and can also increase the packing efficiency of the pleats.

Figure 4(a) shows a pleat of filter medium or filter composite in accordance with another embodiment of the invention. The pleat has an inside and outside surface, and includes two pleat legs 41(a), 41(b), as well as a pleat tip region with an outer end 44. Inner surfaces of the pleat can face and contact each other in or near the vicinity of the pleat tip region. A spacer 45 may lie between the substantially parallel pleat legs 41(a), 41(b), but preferably does not disrupt the contact between the contacting and facing surfaces of the pleat at the pleat tip region. Each of the pleat legs 41(a), 41(b) has a thickness t_2 . At a point 48 spaced a distance in the range from about t_2 to about $4t_2$, preferably about t_2 to $2t_2$, and more preferably about t_2 (i.e., a distance equal to about the thickness of a pleat leg) from the end 44 of the pleat tip region, the thickness of the pleat tip region is no greater than about twice the thickness of a pleat leg 41(a), 41(b), or is less than or equal to about two times t_2 . Thus, the thickness T_2 may be less than or substantially equal to any rational number R times the thickness of a pleat leg where R is less than about two and greater than about zero (e.g., 1.95, 1.5, 1.0). The thickness T_2 at this point 48 is also less than a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 41(a), 41(b). In this embodiment, the point 48 spaced a distance t_2 from the end of the pleat tip region substantially corresponds to a point 43 on the inside surface at the apex 49 of the pleat and opposite the end 44 of the pleat.

As illustrated by the pleat shown in Figure 4(a), a spacer comprising, for example, a drainage layer may be optionally present within the pleat. For example, a spacer may be positioned between adjacent pleat legs, partially or completely filling the space between the pleat legs and/or the facing surfaces at the pleat tip region. The spacer may extend partially or completely into the pleat tip region, or it may terminate short of the pleat tip region. While

a drainage layer has been described as a spacer for illustrative purposes, the spacer may include such structures as adhesive beads, porous strips, or any combination of structures suitable for spacing the facing surfaces of a pleat.

Also, as illustrated by the pleat shown in Figure 4(a), facing inner surfaces of the pleat preferably contact each other at the pleat tip region. By keeping the facing inner surfaces the pleat in contact at a pleat tip region, the pleat tip region is less likely to bulge into a conventional bulbous shape and is more stable. In some embodiments, facing portions of a pleat tip region can be bonded together, thus preventing the pleat tip region from forming a conventional bulbous shape. This adherence and bonding can be facilitated by any suitable method. For example, the facing surfaces of a pleat tip region can be bonded together by contacting and heat bonding the facing surfaces together. Other exemplary methods for contacting and/or bonding facing surfaces at the pleat tip region are described below.

Figure 4(b) shows another pleat in accordance with an embodiment of the invention. The pleat shown in Figure 4(b) includes inner and outer surfaces, two pleat legs 41(a), 41(b) forming a general V-shape, and a pleat tip region including an end 44. Each of the pleat legs 41(a), 41(b) has a thickness t_2 . At a point 48 spaced a distance about t_2 (i.e., about equal to a thickness of a pleat leg) from the end 44 of the pleat, the thickness of the pleat tip region is T_2 . The thickness T_2 is less than a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 41(a), 41(b), and is less than or substantially equal to twice the pleat leg thickness ($2t_2$). Like the embodiment illustrated in Figure 4(a), the point 48 spaced a distance about t_2 from the end 44 substantially corresponds to a point 43 on the inside surface of the pleat at the apex 49.

Figure 4(c) illustrates a pleat of a porous sheet of a filter medium or filter composite according to another embodiment of the invention. The pleat shown in Figure 4(c) includes inner and outer surfaces, two pleat legs 41(a), 41(b), and a pleat tip region with an end 44.

Each of the pleat legs 41(a), 41(b) has a thickness t_2 , while a portion of the pleat at the pleat tip region can have a thickness equal to t_3 , which is less than the pleat leg thickness t_2 . The thickness at the pleat tip region (e.g., t_3) can be less than or substantially equal to any rational number R times the thickness of a pleat leg, where R is less than or equal to 1, but greater
5 than zero (e.g., 0.99, 0.9, 0.75, 0.5, 0.33, 0.2). This thickness (e.g., t_3) can be measured at a point spaced inwardly from the end 44 of the pleat or a point 43 opposite the end 44 (e.g., a distance between about one to about four pleat leg thicknesses from the end 44 of the pleat).

The thickness of the porous sheet can be reduced prior to, concurrent with, or after the formation of the pleats. In one example, a porous sheet of filter medium or filter composite
10 can be pre-scored with a plurality of substantially parallel lines or stripes, so that the scored lines substantially correspond to the later formed apexes and/or a portion of all of the pleat tip region of the resulting pleated structure. The scoring process can reduce the thickness of the filter medium or the filter composite at the pleat tip region of the pleat, e.g., by pressing score lines into the medium or composite with a pressure applicator such as a roller and/or heater.
15 Scoring processes in accordance with embodiments of the invention are discussed in more detail below. Alternatively, the thickness of the sheet can be reduced concurrent with the formation of the pleats. In another example, a porous sheet can be pleated by conforming the porous sheet around one or more heated or non-heated mandrels or dies. Pressure and/or heat from the mandrel or dies can be applied to the outer and/or inner surface of the sheet to
20 reduce the thickness of the sheet at the pleat tip region (e.g., by melting and/or compression of the sheet) while the pleat is being formed.

Again with reference to Figure 4(c), at a point 48 spaced a distance about t_2 (i.e., about equal to the thickness of a pleat leg) from the end 44 of the pleat, the thickness of the pleat tip region is T_2 . The thickness T_2 is less than or substantially equal to about twice the
25 thickness of one of the pleat legs 41(a), 41(b) or about two times t_2 . The thickness T_2 is also

less than a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 41(a), 41(b). Unlike the embodiments illustrated in Figures 4(a) and 4(b), the point 48 spaced a distance about t_2 from the end 44 of the pleat does not substantially correspond to a point 43 on the inside surface of the pleat at the apex 49 and opposite the end 44 of the pleat.

5 In addition, unlike the embodiment shown in Figure 4(a), facing surfaces of the pleat at the pleat tip region do not contact each other. Although facing surfaces of the pleat at the pleat tip region do not contact each other in the illustrated embodiment, the shape of the pleat tip region remains substantially non-bulbous. Alternatively, facing surfaces of the pleat tip region (e.g., including the point 43 opposite the end 44 of the pleat) may contact each other
10 to, e.g., improve the stability of the pleat tip region, and/or reduce the likelihood that pleat tip region will form into conventional bulbous shape. As explained previously, a pleated filter element without conventional bulbous shaped pleat tip regions can advantageously provide the filter element with a higher packing efficiency and a reduced pressure differential across the filter element.

15 In some embodiments, a porous sheet having one or more layers of filter medium or filter composite may be pre-scored with substantially parallel lines having any suitable width, prior to pleating the sheet. The scoring of the sheet may occur in any suitable manner, including heating, scribing, melting, embossing and/or pressing. The scoring of the sheet can be performed with any suitable device, including a rotary pleater, edge knife, roller, die, etc.
20 Preferably, the scoring of the sheet forms pre-scored regions of reduced thickness relative to other portions of the sheet. For example, a porous polymeric sheet of filter medium or composite can be scored by pressing substantially parallel lines in the sheet with one or more heated or non-heated pressure applicators (e.g., rollers, blades). Heat and/or pressure from the pressure applicator(s) can melt and/or reduce the thickness of the sheet, thus forming pre-
25 scored regions. This pre-scored sheet can then be pleated. For example, the scored sheet can

be formed into a pleated filter medium or composite by folding the sheet multiple times in a zig-zag manner so that pre-scores on the sheet substantially correspond with the apexes of the resulting pleated filter medium or filter composite.

In one embodiment, a sheet of filter medium or filter composite may be scored to
5 create a discontinuous surface on one side and a continuous surface on the other. The sheet can then be pleated so that the continuous surface side of the sheet forms the end of the pleat. This can be more clearly illustrated in Figures 9(a) and (b). Figure 9(a) illustrates a sheet of filter medium or filter composite having a thickness t_2 at a non-scored region and a thickness t_3 at a pre-scored region 90. The sheet includes a discontinuous surface 91 and a continuous
10 surface 92. The sheet can then be pleated so that side having the continuous surface 90 forms the end 44 of the pleat. The resulting pleat is shown in Figure 9(b). The pleat shown in Figure 9(b) is similar in shape to the pleat shown in Figure 4(c), except that the pleat in Figure 9(b) shows contacting pleat legs. Advantageously, by contacting the legs of the pleats in a pleated structure, the number of pleats per length can be increased, thus increasing the
15 filter capacity of the pleated structure.

In another embodiment, the pre-scored sheet can then be pleated so that the discontinuous surface side of the sheet forms the end of the pleat. This can be more clearly illustrated in Figures 9(c) and 9(d). Figure 9(c) illustrates a sheet of filter medium or filter composite having a thickness t_2 at a non-scored region and a thickness t_3 at a pre-scored
20 region 90. The sheet includes a discontinuous surface 91 and a continuous surface 92. The sheet can then be pleated so that the discontinuous surface side 90 of the sheet forms the end of the pleat 44. The resulting pleat is shown in Figure 9(d).

The pleats shown in Figures 9(b) and 9(d) each include inner and outer surfaces, two pleat legs 41(a), 41(b), and a pleat tip region with an end 44. Each of the pleat legs 41(a),
25 41(b) has a thickness t_2 . The thickness of the sheet at the pleat tip region (e.g., t_3) can be less

than or substantially equal to any rational number R times the thickness of a pleat leg, where R is less than or equal to 1, but greater than zero (e.g., 0.99, 0.9, 0.75, 0.5, 0.33, 0.2). This thickness (e.g., t_3) can be measured at a distance inward from the end 44 of the pleat or a point 43 opposite the end 44 of the pleat (e.g., between about one to about four pleat leg thicknesses from the end 44 of the pleat tip region). At a point 48 spaced about one pleat leg thickness t_2 from the end 44 of the pleat tip region, the thickness of the pleat tip region can be T_2 . This thickness, T_2 , can be less than or equal to a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 41(a), 41(b), and less than or equal to twice the pleat leg thickness ($2t_2$). The pleat tip region of the pleat shown in Figs. 9(b) and (d) can be structurally stable, thin, and easily formed.

Alternatively, the porous sheet can be pre-scored so that discontinuous surfaces are present on opposing sides of the sheet. This is more clearly illustrated with respect to Figures 9(e) and 9(f). Figure 9(e) illustrates a sheet of filter medium or filter composite having a thickness t_2 at a non-scored region and a thickness t_3 at a pre-scored region 90. The sheet includes a first discontinuous surface 91(a) on one side of the sheet and a second discontinuous surface 91(b) on the other side of the sheet. As shown in Figure 9(e), the discontinuities on opposing sides of the sheet can substantially correspond to each other, and can be formed by, e.g., scoring opposite sides of the sheet. Scoring opposite sides of the sheet may increase the stability of the pleat tip region by ensuring that the material at both sides of the sheet is sufficiently compressed. The sheet can then be pleated. The resulting pleat is shown in Figure 9(f).

The pleat shown in Figure 9(f) includes inner and outer surfaces, two pleat legs 41(a), 41(b), and a pleat tip region with an end 44. Each of the pleat legs 41(a), 41(b) has the thickness t_2 . The thickness of the sheet at the pleat tip region (e.g., t_3) can be less than or substantially equal to any rational number R times the thickness of a pleat leg, where R is less

than or equal to 1, but greater than zero (e.g., 0.99, 0.9, 0.75, 0.5, 0.33, 0.2). This thickness (e.g., t_3) can be measured at a distance inward from the end 44 of the pleat or a point 43 opposite the end 44 of the pleat (e.g., between about one to about four pleat leg thicknesses from the end 44 of the pleat tip region). At a point 48 spaced about one pleat leg thickness t_2 from the end 44 of the pleat tip region, the thickness of the pleat tip region can be T_2 . This thickness, T_2 , can be less than a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 41(a), 41(b), and less than twice the pleat leg thickness ($2t_2$).

Pre-scoring a porous sheet and then pleating the porous sheet can be advantageous. For example, pre-scoring a porous sheet before pleating can impart added stability to the subsequently formed pleat tip region, and can make the pleating process easier by, e.g., providing easily identifiable and foldable regions on the porous sheet. In particular, such a process can be especially suitable for forming a stable, pleated polymeric filter such as a pleated fluoropolymeric filter. For example, a somewhat springy porous sheet of filter medium or filter composite can be easily pleated by, e.g., providing the sheet with pre-scored regions having a reduced thickness and then pleating the sheet along the pre-scored regions.

However, in a preferred embodiment, the pleat tip region is reformed rather than pre-scored or in addition to being pre-scored. For example, a filter medium or filter composite can be corrugated in a conventional corrugator, forming one or more pleats with pleat tip regions. Preferably, one or more, and more preferably all, of the pleat tip regions, including the entire region or continuous or discontinuous portions of each pleat tip region, thereafter may be reformed to ensure the pleat tip regions do not have a conventional bulbous shape.

If discontinuous portions of the pleat tip region are reformed, the end of the pleat tip region may or may not be reformed. For example, a portion of the pleat tip region spaced from the end of the pleat, but not including the end of the pleat, can be reformed to ensure that the pleat tip region (e.g., as a whole) does not have a conventional bulbous shape. In one

illustrative example, facing inner surfaces of the pleat tip region spaced from the end of the pleat, but not including the end of the pleat, can bond together by any suitable method (heat, pressure, adhesive, etc.), thus ensuring that the pleat tip region does not form a conventional bulbous shape and/or does not extend beyond corresponding points on opposing outer
5 surfaces of the pleat legs of the pleat. The portion of the pleat tip region including the bonded region can be spaced one to four pleat leg thicknesses from the end of the pleat tip region and can have a thickness less than about twice the pleat leg thickness.

Reforming methods may include any method which may alter the shape, the composition and/or the internal or external structure of a pleat tip region of a pleat to set the
10 pleat tip region in a non-bulbous shape. Reforming methods may include the application of pressure and/or heat to the pleat tip regions by, e.g., molding, squeezing, crushing, welding, pressing, melting, softening, heating, or any combination of these procedures. Another reforming method may be molding a pleat tip region with pressure, alone or in combination with sonic energy (e.g., ultrasonic) and/or electromagnetic energy (e.g., a radiant heater).
15 Any suitable pressure applicator (e.g., a pair of dies) can shape the pleat tip region by applying pressure to the pleat tip region, for example, on opposite sides of the outer surface of the pleat tip region. Consequently, the applied pressure can bond facing surfaces of the pleat tip region together by, e.g., causing the facing surfaces to intermix or commingle with one another. Preferably, ultrasonic heating and/or welding can be used to reform the pleat tip
20 regions, because ultrasonic heating and/or welding can be performed relatively quickly. Alternatively, the facing surfaces of a pleat at a pleat tip region can bond together by other processes including using an adhesive to bond facing surfaces of the pleat tip region together or solvent bonding facing surfaces of the pleat tip region together.

After the pleat tip regions of the pleats are reformed, the resulting pleat tip regions
25 may have a different composition, internal structure, and/or shape than before the reforming

process. For example, if a pleat tip region of a pleat is reformed with heat and pressure, the resulting pleat tip region may comprise not only a reformed shape, but also a fused or solid portion. The fused or solid portion may result from the softening, melting or liquification of the material of the filter medium in the pleat tip region during reformation. For example, a

5 pleat tip region of the pleat may include a porous sheet, such as a fibrous layer or a membrane, made of a low melting point material. The pleat tip region may be heated to reform the pleat tip region. The heat softens or melts the low melting point material, which partially or fully eliminates pores in the pleat tip region, thus creating a partially or fully solid structure in the pleat tip region. Pores in a pleat leg can be unaffected by the pleat tip region

10 reformation process. Alternatively, the pores in the pleat tip region may be unaffected by the application of heat and/or pressure. Illustrative methods and systems for reforming the pleat tip regions of pleated filter media are shown in Figures 5-8.

Figure 5 illustrates a shaping apparatus 57 for reforming the pleat tip regions of a corrugated structure such as a filter medium or filter composite, which has been previously

15 corrugated in any conventional manner. The shaping apparatus 57 can include two dies 54, 55, either or both of which may be movable. The dies 54(a), 55(a) are preferably moveable in directions generally perpendicular to the direction of the pleat having its pleat tip region reformed. For example, the dies 54(a), 55(a) may reform the pleat tip region by applying pressure and/or heat to opposing outer surfaces of the pleat tip region. Each of the dies 54,

20 55, can include a shaping portion 54(a), 55(a) which, when pressed together, may form a desired pleat tip region shape. For example, when pressed together, cooperating shaping portions 54(a), 55(a) may cooperate to form any of the pleat tip region shapes previously mentioned (e.g., pointed, tapered, rounded). This pressing can also bond facing surfaces of the pleat tip region together (e.g., by causing the facing surfaces to contact each other and

25 liquefy). Although the shaping apparatus 57 illustrated in Figure 5 has two dies 54, 55, the

shaping apparatus 57 may include any suitable number of dies cooperating to form a desired non-bulbous pleat tip region shape. For example, the shaping apparatus 57 may include three dies, which cooperate to form a desired pleat tip region shape.

Although the shaping apparatus 57 may reform the pleat tip regions solely by the application of pressure, the shaping apparatus 57 or the dies 54, 55 of the shaping apparatus 57 may include additional reforming devices (not shown), such as electromagnetic or sonic energy generating devices (e.g., an electric or radiant heater, an ultrasonic generator). For example, one or both of the dies 54, 55 of the shaping apparatus 57 may include a heating device so that heat can be supplied to the pleat tip region being reformed. Heat and pressure from the dies 54, 55 can work in combination to soften and melt the material in the pleat tip region of the pleat, thus increasing the speed and decreasing the difficulty of the reforming process. If heat and pressure are used to reform the pleat tip regions of the pleats, heat and pressure can be applied sequentially (e.g., first heat and then pressure, or the reverse) or concurrently.

In addition, although the shaping apparatus 57 illustrated in Figure 5 includes a pair of dies 54, 55, the shaping apparatus need not include movable dies or the application of pressure. The shaping apparatus may reform the pleat tip regions solely by the application of heat. For example, the shaping apparatus may comprise a device such as an ultrasonic energy generating device and no dies, so that ultrasonic energy is the primary method for reforming the pleat tip region of the pleat.

An illustrative method for reforming the pleat tip regions of a pleated filter medium or composite can be described with reference to Figure 5. A pleated filter medium or composite 51 can initially be formed by pleating a sheet of filter medium or composite with a corrugator (not shown), which may or may not be in operative communication with the shaping apparatus 57. For example, a porous sheet of filter medium or composite can be corrugated

through a conventional corrugator, thereby forming a pleated filter medium or composite 51 having pleat tip regions, which may include a bulbous shape. For example, one or more layers comprising the filter medium or the filter composite may be formed into a laminate or composite and then co-corrugated to produce a plurality of pleats. Beginning at one end of the plurality of unreformed pleats 51, an individual pleat 58 may be arranged to separate or position the pleat tip region away from the other pleats so that the pleat tip region may be conveniently introduced to the shaping apparatus 57. Once the pleat tip region of the individual pleat 58 is positioned between the dies 54, 55 of the shaping apparatus 57, one or both of the dies 54, 55 of the shaping apparatus 57 may reform the pleat tip region by moving toward each other and toward the pleat tip region in directions generally perpendicular to the pleat 58. Heat and/or pressure can then be applied to the opposing outer surfaces of the pleat tip region to reform it, e.g., fashion it in any of the previously mentioned shapes embodying the invention. Once the pleat tip region is reformed, one or both of the dies 54, 55 can move away from the pleat 58, releasing the reformed pleat tip region. The pleat 58 having the reformed pleat tip region can then be repositioned adjacent to other pleats 52 having reformed pleat tip regions. This process may be repeated until a desired number (e.g., substantially all) of the pleat tip regions along one side of the pleated filter medium or composite 51 have been reformed.

Figures 6-8 show one example of a process for forming a filter pack. In the methods illustrated in Figures 6-8, a spacer 59, such as a woven or nonwoven fabric or mesh, is inserted within each pleat and/or between adjacent pleats of the pleated filter medium or filter composite to form a filter pack. Figure 6 shows a method for forming a filter pack having a spacer and a pleated filter medium or filter composite with reformed pleat tip regions. The shaping apparatus 57 shown in Figure 6 may be similar to the shaping apparatus described in Figure 5. Like the method shown in Figure 5, an individual pleat 58 can be positioned away

from other pleats 51 and the pleat tip region of the positioned pleat 58 can be introduced between the dies 54, 55 of the shaping apparatus 57. The dies 54, 55 can then reform the pleat tip region by applying heat and/or pressure to the opposing outer surfaces of the pleat tip region. After the pleat tip region is reformed, the pleat tip region may have facing
5 surfaces contacting and/or bonded to each other. As the pleat 58 is repositioned onto the stack of pleats 52 having reformed pleat tip regions, a spacer 59 may be placed between the pleat having a previously reformed pleat tip region and the pleat 58 most recently having its pleat tip region reformed. The relatively wide space created between the positioned and repositioned pleats can also permit the pleat faces to be treated (e.g., coated with an adhesive)
10 in a quick and efficient manner, if desired. Subsequently, the pleat 58 having the reformed pleat tip region can be repositioned adjacent to the spacer 59. This process can be repeated to form a filter pack 53 having plurality of spacers 59 between adjacent pleats, and a pleated filter medium or filter composite having reformed pleat tip regions.

While the method illustrated in Figure 6 shows a spacer inserted between adjacent
15 pleats immediately after each pleat tip region is reformed, alternative embodiments may insert the spacer after the reformed pleat is repositioned or before the pleat tip region is reformed, e.g., immediately before. For example, Figure 7 shows another method for forming a filter pack 62. The shaping apparatus 57 may be similar to the previously described shaping apparatus. However, unlike the previously described embodiments, a
20 plurality of spacers 59 are positioned between adjacent pleats and/or within each pleat before the pleat tip regions are reformed. When the pleat tip region of a pleat 58 is reformed with a spacer within the pleat 58, the spacer and the filter medium or filter composite may be integrally attached or bonded at the pleat tip region. For example, the spacer 59 in the pleat 58 having its pleat tip region reformed may comprise a material with a lower melting point
25 than the surrounding filter medium or filter composite portions. During the reformation of

the pleat tip region by the dies 54, 55 of the shaping apparatus 57, the material of the spacer can melt and impregnate the surrounding filter medium or filter composite. The resulting reformed pleat tip region can comprise an inter-bonded structure of filter medium or filter composite material and spacer material. This inter-bonded structure can result in a pleat tip region with increased structural stability and a decreasing ability to reform into a bulbous-shape. After the pleat tip region of the pleat 58 is reformed, the reformed pleat tip region can be removed from the shaping apparatus 57 and repositioned next to other pleats with reformed pleat tip regions to form a filter pack 62. After the desired number of pleat tip regions on one side of the filter pack 62 have been reformed, the pleat tip regions on the other side of the formed filter pack 62 may be reformed in a similar or different manner.

In the previous embodiment, the spacer was bonded within each reformed pleat tip region. Alternatively, a spacer may be positioned within a pleat or between pleats, but not be bonded within the pleat tip region. For example, a spacer may be present within a pleat between the legs of the pleat, but not between facing surfaces of the pleat tip region. In this instance, the spacer is within the pleat, but is largely unaffected by the pleat tip region reforming procedure. In this regard, the spacer may occupy substantially all or a portion of the space between pleats or within a pleat.

Figure 8 shows another embodiment of the invention. The system shown in Figure 8 includes first and second shaping apparatuses 57(a), 57(b) on opposing sides of a conveying apparatus 81. The conveying apparatus 81 can define a serpentine-like conveying path with one or more curves such as oppositely bending curves 81(a), 81(b), 81(c). In the illustrative method, a pleated filter medium or composite 61 having unreformed pleat tip regions can be conveyed in a path defined by the conveying apparatus 81. As the pleated filter medium composite 61 having unreformed pleat tip regions approaches a first curve 81(a) in the path defined by the conveying device 81, the pleats or the spaces on the first side of the pleated

filter medium or filter composite 61 can gradually open, and spacers 59 may be inserted in the spaces between the pleats. The pleated filter medium or filter composite 61 and the spacer(s) 59, can then travel towards the first shaping apparatus 57(a) which may be positioned proximate a second curve 81(b) in the path defined by the conveying device 81.

- 5 As the pleated filter medium or composite 61 approaches the curve 81(b), the pleats or spaces on the second side of the pleated filter medium or filter composite 61 gradually open. The first shaping apparatus 57(a) can then reform the pleat tip regions on the second side in any suitable manner such as those previously described. Additional spacers 59 can also be inserted between the spaces or pleats on the second side. The pleat tip region reforming
10 process can be repeated until the desired number of pleat tip regions, preferably all of them, have been reformed.

- Then, the pleated filter medium or composite 61 can travel towards a second shaping apparatus 57(b) located proximate a third curve 81(c) defined by the conveying apparatus 81. The second shaping apparatus 57(b) can be located on the first side of the conveying
15 apparatus 81, opposite the first shaping apparatus 57(a). As the pleated filter medium or composite having reformed pleat tip regions on the second side approaches the curve 81(c), the spaces or pleats on the first side, i.e., the side having unreformed pleat tip regions, gradually open. Once the spaces between the pleats have opened, the second pleat shaping apparatus 57(b) can reform the unreformed pleat tip regions on the first side in any suitable
20 manner such as those previously described. The filter pack 62 leaving the second shaping apparatus 57(b) may have a pleated filter medium or filter composite with reformed pleat tip regions on both sides, and spacers 59 between and/or within the pleats. Thus, the system shown in Figure 8 can produce a filter pack in a continuous and efficient manner.

- The filter medium may be selected in accordance with several factors, including the
25 nature of the fluid being filtered, the nature and size of the contaminants in the fluid, and the

acceptable pressure drop across the filter medium. The filter medium may comprise a wide variety of porous microfiltration or ultrafiltration media. The filter medium may consist of only a single sheet or layer or it may comprise multiple sheets and/or layers. If the filter medium comprises multiple layers, it is not necessary that all layers have the same material, shape, thickness or structure.

The filter medium may include any suitable structure and/or material. For example, the filter medium may be a porous sheet such as a supported or unsupported membrane, or a woven or nonwoven fibrous or filamentous sheet, and may be fabricated from a natural or synthetic polymer, glass, ceramic or metal. Preferably, the filter medium comprises a polymeric material, more preferably a fibrous polymeric material, which is substantially free of boron. Polymeric materials may include polyolefins such as polypropylene and polyethylene; fluoropolymers such as PTFE, fluorinated ethylenepropylene (FEP), and perfluoroalkoxy polymers (PFA); polyamides such as nylon and polyaramid; and polyesters. Advantageously, polymeric filter media are less likely to splinter and break than other filter media (e.g., glass), and are less likely to produce contamination (e.g., boron containing contaminants). Other preferred media may include a family of fibrous filter media having various binder resins, and are available from Pall Corporation under the trade names Ultipor® and Pallflex®. Further, the filter medium may be a porous sintered sheet of metallic or ceramic material, such as a sheet of sintered metal powder, fibers and/or filaments.

Furthermore, the filter medium may have any desired pore structure, including a graded pore structure, and any desired nominal pore size. The filter medium may also include an electrostatic charge (e.g., an electret filter medium). By providing an electrostatic charge to the filter medium, particulate contaminants can be trapped electrically as well as

mechanically. For example, a temporary or permanent electrical charge can be imparted to a polypropylene melt-blown nonwoven web.

The filter medium can also have any suitable removal rating or filtration efficiency. Preferably, the filter medium has high filtration efficiency. For example, the filter medium may have a HEPA (high efficiency particulate air), an ULPA (ultra low penetration air) or a super ULPA removal rating. Preferably, the filter medium can have a removal rating up to 0.1 or 0.3 microns or more, of R, where R is any rational number greater than or equal to about 85% and less than or equal to 100%. Exemplary values of R include: 85.0, 90.0, 95.0, 97.0, 99.5, 99.9, 99.97, 99.997, 99.999, or 99.9999 percent. If the filter medium comprises plural layers, one or more layers may have a HEPA, ULPA, or super ULPA rating. The desired removal rating of the filter medium may depend on the environment in which the filter is employed. For example, particulate filters used in aircraft preferably have a removal rating of at least about 85%, and in clean rooms at least about 99.997%.

The filter medium may form part of a filter composite. In addition to a pleated filter medium, a filter composite may optionally include one or more drainage layers upstream and/or downstream of the filter medium, and/or cushioning layers between the one or more drainage layers and the filter medium.

If the filter composite includes drainage layers, the drainage layers are preferably very open, allowing fluid to flow laterally and to uniformly distribute the fluid across the surface of the filter medium. Thus, the drainage layers typically have a very low edgewise flow resistance, and are much coarser than the filter medium. The drainage layers can also prevent pleated surfaces of the filter medium from coming into contact with one another and thereby reducing the effective surface area of the filter medium. The drainage layers can thus provide positive spacing between adjacent pleats of the filter medium. Further, the drainage layers

can be loose or one or more drainage layers can be laminated to one another to provide stiffness to the filter composite and/or improve the shape of the pleat.

Any suitable woven or nonwoven material having good porosity can be used for an upstream drainage layer and/or downstream drainage layer. Furthermore, either layer may be fabricated from one or more of natural fibers, polymeric materials, and/or glass fibers. In a preferred embodiment, the upstream drainage layers comprise mesh, such as an extruded polymeric mesh. The mesh can be fabricated from any polymeric material, including polyester, polypropylene, or polyamide such as nylon, which is suitable for the fluid being filtered and for the applicable filtration parameters such as temperature. The mesh is preferably as smooth as possible to reduce abrasion between it and the underlying layers. Extruded polymeric mesh is generally preferable to other support and drainage materials, including woven and nonwoven fibrous webs and polymeric netting, because it is so smooth and has such a low edgewise flow resistance and because it typically does not shrink during fabrication and corrugation of the filter element.

A principal purpose of the cushioning layer is to prevent abrasion between the drainage layer and the filter medium. The drainage layer typically has good drainage properties because it is fashioned from relatively large fibers or filaments. Consequently, it generally has a rougher surface than the filter medium. When such a material is laminated directly to the filter medium, for example, significant abrasion of the filter medium may result when the filter medium undergoes flexing, for example, due to pressure cycles, and the drainage layer repeatedly rubs against the filter medium. However, when a cushioning layer, which is smoother than a drainage layer and tougher than a filter medium, is interposed between a drainage layer and a filter medium, the abrasion of the filter medium can be greatly reduced, resulting in an increase in the useful life of the filter medium, or corresponding filter pack or filter element.

The cushioning layer is preferably formed of a thin, very porous material. It is also preferably formed from a material which can be characterized as smooth or as smooth and tough. For example, it may be a non-abrasive, nonwoven material with a high tensile strength. A preferred material for the cushioning layer is a wet-laid polyester nonwoven material sold by Hirose Corporation under the trade designation 05TH08. Other preferred materials include a nylon nonwoven material available from Fiberweb North America Inc. under the trade designation Cerex and a nonwoven polyester material available from Reemay Corporation under the trade designation Reemay, such as Reemay 2006 or Reemay 2250.

A filter pack according to embodiments of the invention may include any of the above described filter media or filter composites (e.g., filter laminates). In addition, a filter pack may optionally include spacers. Spacers may include any suitable article which can space surfaces of adjacent pleats or surfaces of a pleat. Exemplary pleat spacers may include combs or structures which fit over the tips of the pleats, or structures such as polymeric beads (e.g., hardened adhesive) or fibrous media (strips) which may lie between the pleats to maintain pleat spacing. Pleat spacers may even include structures, such as dimples or ridges, which are integrally formed in the pleats, for example, in the legs of the pleats, to space adjacent pleat surfaces.

A pleated filter medium, filter composite, or filter pack according to embodiments of the invention can be incorporated into any suitable filter element and can be used in any suitable form. The shape of the filter element is not restricted and may be cylindrical, for example, or parallelepiped. In a preferred embodiment, the filter element may include a frame (e.g., a box-shaped frame) having a pleated filter medium or filter composite including a pleated filter medium or composite disposed in and sealed against the frame. For example, a pleated filter composite having pleat tip regions with a predetermined shape (e.g., tapered) can be mounted within and sealed to a wood, plastic, or metal frame with a potting material

such as polyurethane, epoxy, silicone, hot-melt adhesive or plastisol. A filter element having a framed pleated filter medium, filter composite or filter pack can be used, for example, to purify the air or an aircraft cabin or a clean room.

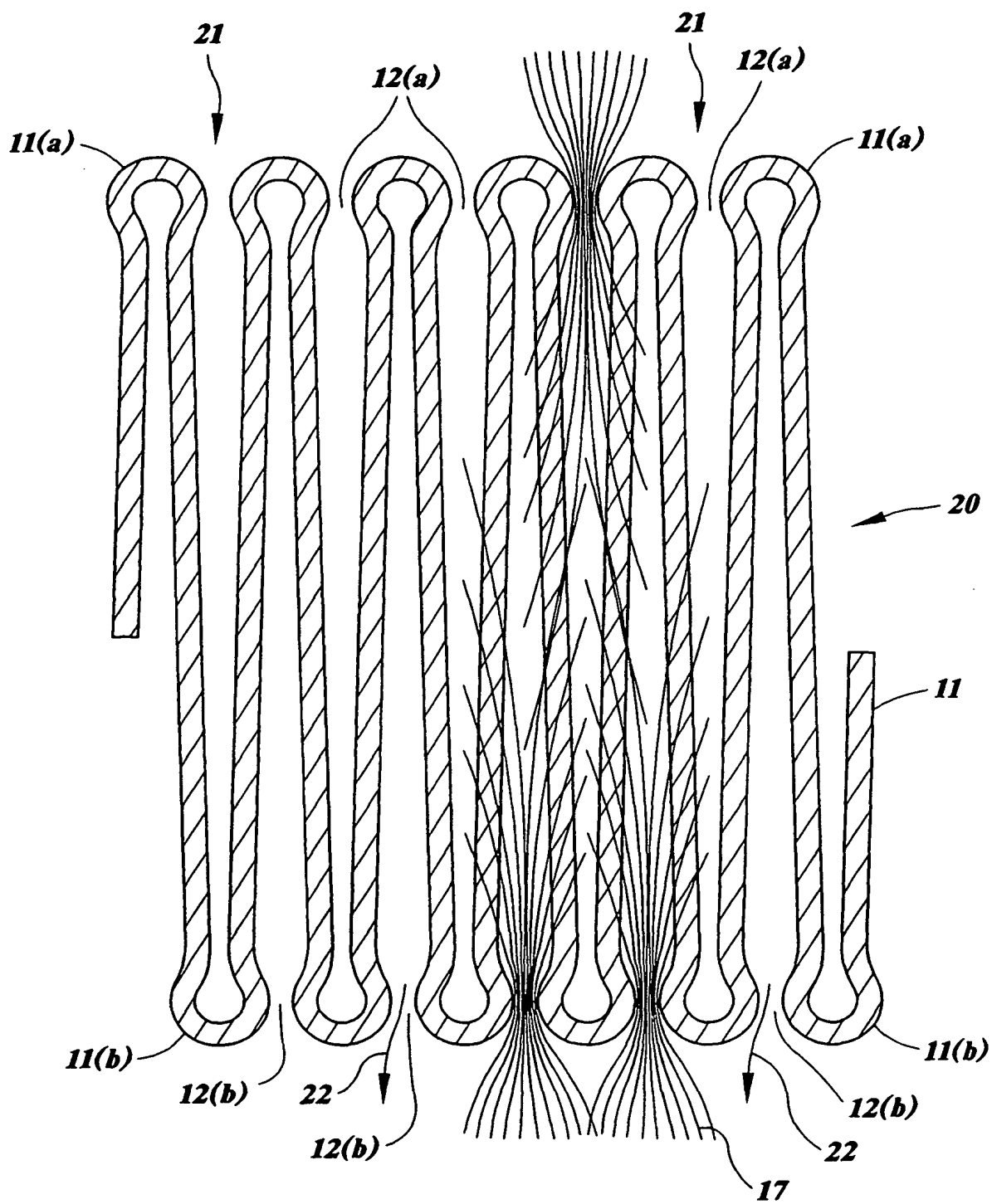
Alternatively, the filter element may comprise a cylindrical structure. A cylindrical
5 filter element may include a previously described pleated filter medium or composite formed in a cylinder around a rigid cylindrical core. Pleat tip regions embodying the invention may be incorporated only at the radially inward roots of the pleats, only at the radially outward crests of the pleats, or both. End caps may secure the cylindrical pleated filter medium to the rigid cylindrical core. If desired, a wrap, cage or other support structure may be disposed
10 around the cylindrical, pleated filter medium or filter composite. Preferably, the filter element can be removable and replaceable when the filter element outlives its useful life (e.g., becomes fouled or damaged).

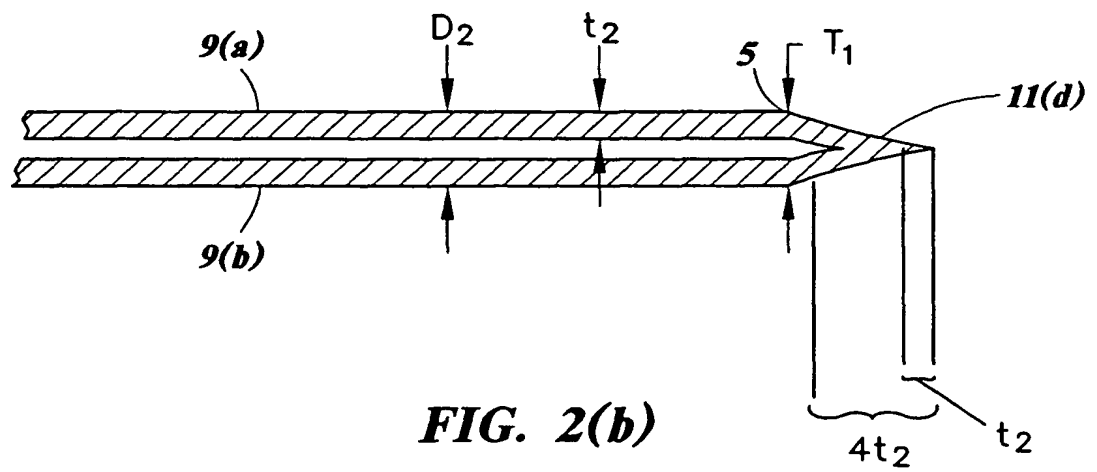
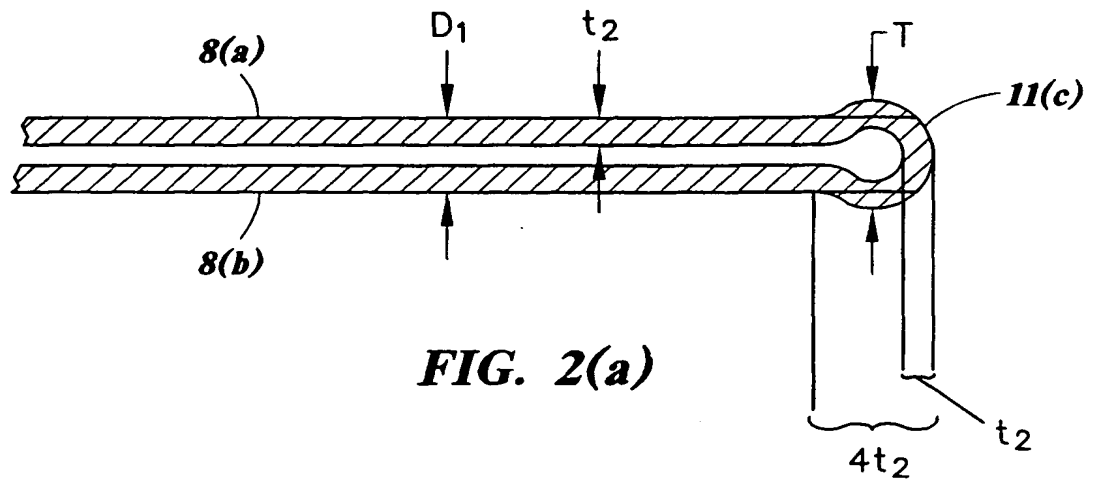
While the invention has been described in some detail by way of illustration and example, it is understood that the invention is not restricted to the specifically described
15 embodiments in the specification. For example, the present invention encompasses the combination of one or more of the features of any of the embodiments previously described or illustrated with one or more of the features of the other embodiments. Thus, a pleat described or illustrated for any of the embodiments (e.g., Figure 4(a)) may be combined in a filter with a pleat described or illustrated for another embodiment (e.g., Figure 4(c)) and still
20 be encompassed by the invention. The present invention also encompasses any of the embodiments previously described or illustrated where one or more of the features of the embodiment are modified or deleted. As an example, the spacer 45 described and illustrated for the embodiment shown in Figure 4(c)) may be deleted and the pleat is still encompassed by the invention. Thus, the invention includes all modifications, equivalents, and alternatives
25 falling within the spirit and scope of the invention.

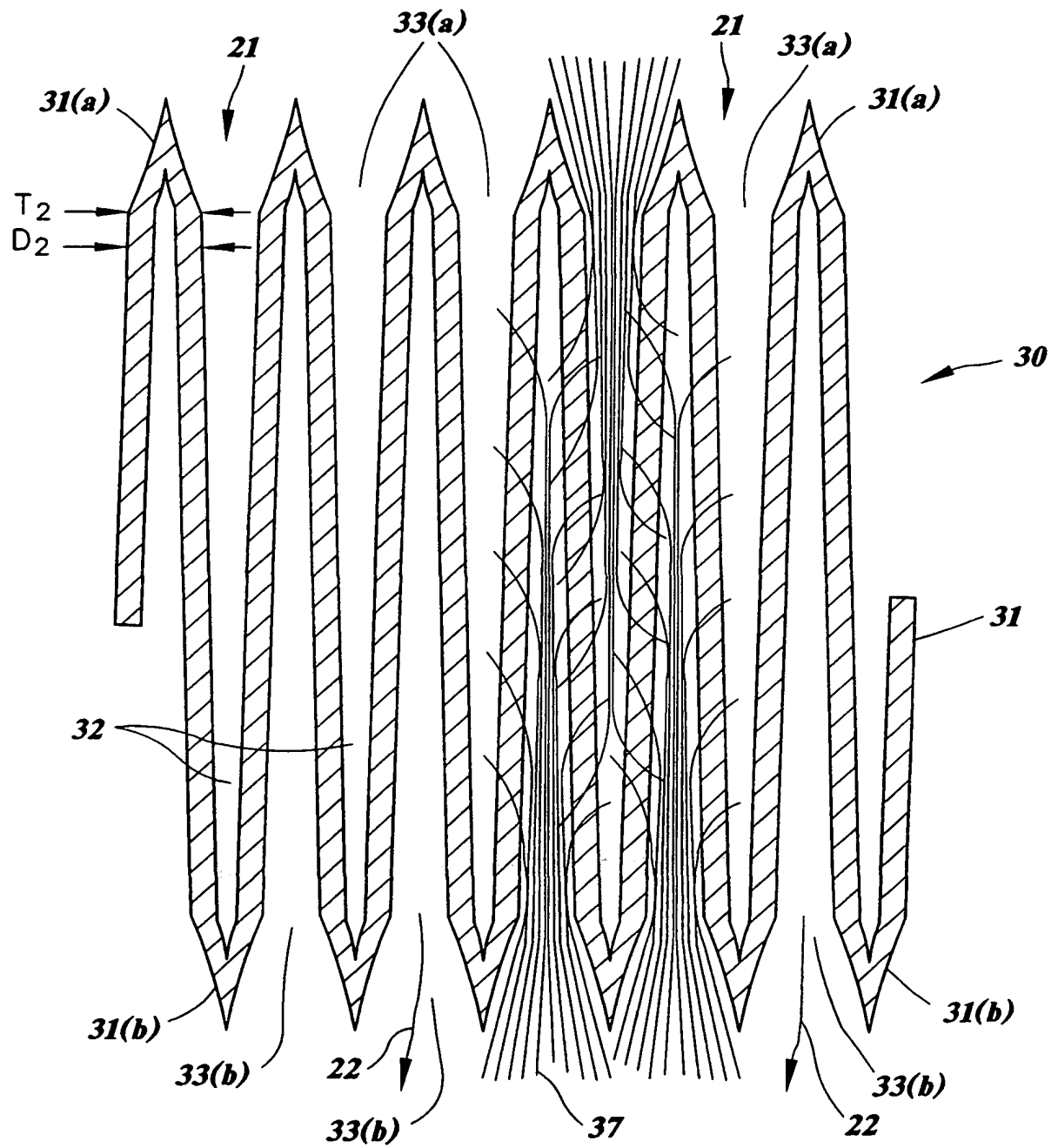
Claims:

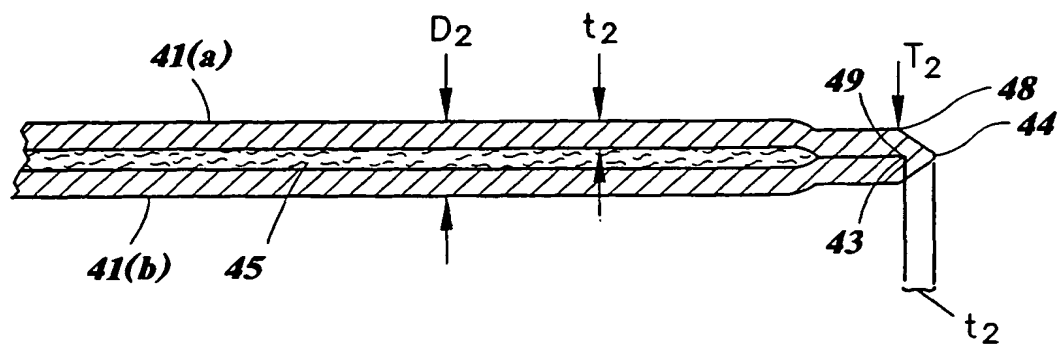
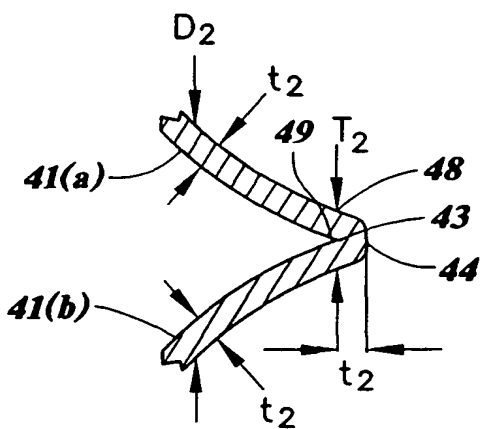
1. A filter comprising:
a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region, wherein a thickness of the pleat tip region at a point spaced about one to four pleat leg thicknesses from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness.
5
2. A filter comprising:
a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region,
10 wherein a thickness of the pleat tip region at a point spaced about one to four pleat leg thicknesses from the end of the pleat tip region is less than or equal to a distance between corresponding points on opposing outer surfaces of the pleat legs.
- 15 3. A filter comprising:
a pleated structure having a plurality of pleats and more than one layer, at least one of the pleats having a reformed pleat tip region.
- 20 4. A filter comprising:
a pleated structure having a plurality of pleats and a pair of pleat legs, at least one of the pleats having a reformed pleat tip region and contacting pleat legs.
- 25 5. A filter comprising:
a plurality of pleats, at least one pleat including a pleat tip region having contacting inner surfaces.
6. A filter comprising:
a pleated porous sheet having a polymeric material and a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region, wherein the sheet includes a pre-scored region at the pleat tip region.
30
7. A method of making a filter comprising:
forming a plurality of pleats having pleat tip regions; and
applying pressure to opposing outer surfaces of at least one pleat tip region.
35
8. A method of making a filter comprising:
forming a plurality of pleats free of bulbous pleat tip regions.
- 9 A method of making a filter comprising:
40 forming a plurality of pleats wherein a thickness of each pleat tip region at a point spaced about one to about four pleat leg thicknesses from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness.
10. A method of making a filter comprising:
45 forming a plurality of pleats wherein a thickness of each pleat tip region at a point spaced about one to about four pleat leg thicknesses from the end of the pleat tip region is less than or equal to a distance between corresponding points on opposing outer surfaces of the pleat legs.

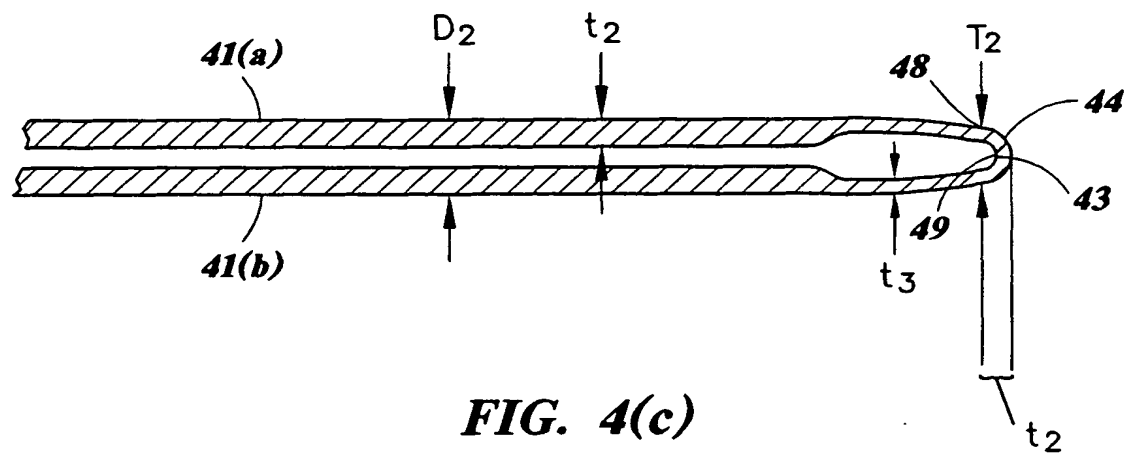
11. A method of making a filter comprising:
scoring a porous sheet including a polymeric material; and
pleating the porous sheet.
12. An apparatus comprising:
one or more dies arranged to reform a pleat tip region of a pleat.
13. A filter made by the method or apparatus of any of claims 7-12.
14. The filter, method or apparatus of any of the preceding claims wherein the filter includes pleat legs generally parallel to each other.
15. The filter, method or apparatus of any of the preceding claims wherein the filter comprises a fluoropolymeric material.
16. The filter, method or apparatus of any of the preceding claims wherein the filter includes more than one layer.

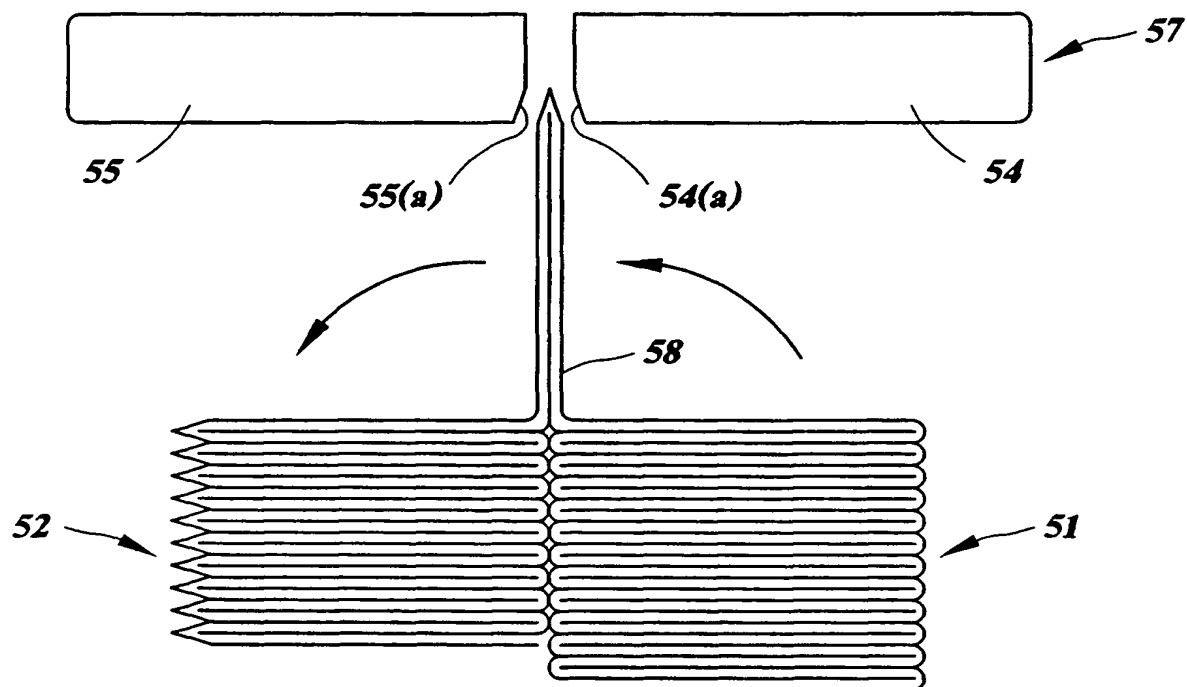
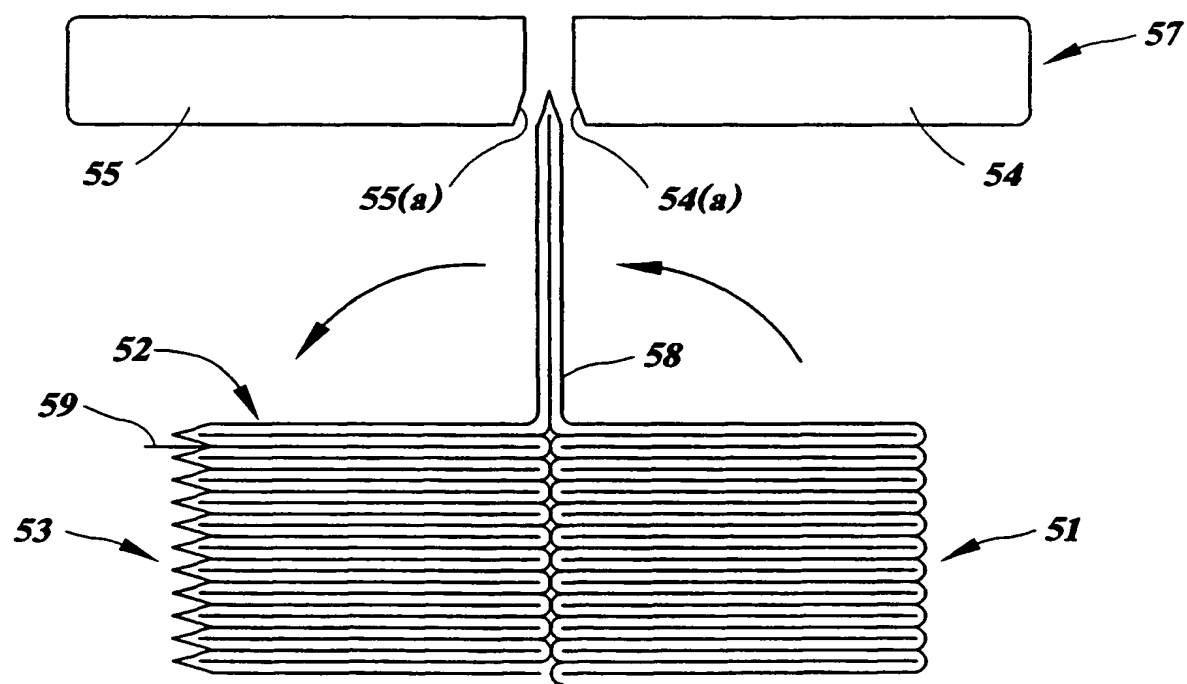
1/11**FIG. 1**

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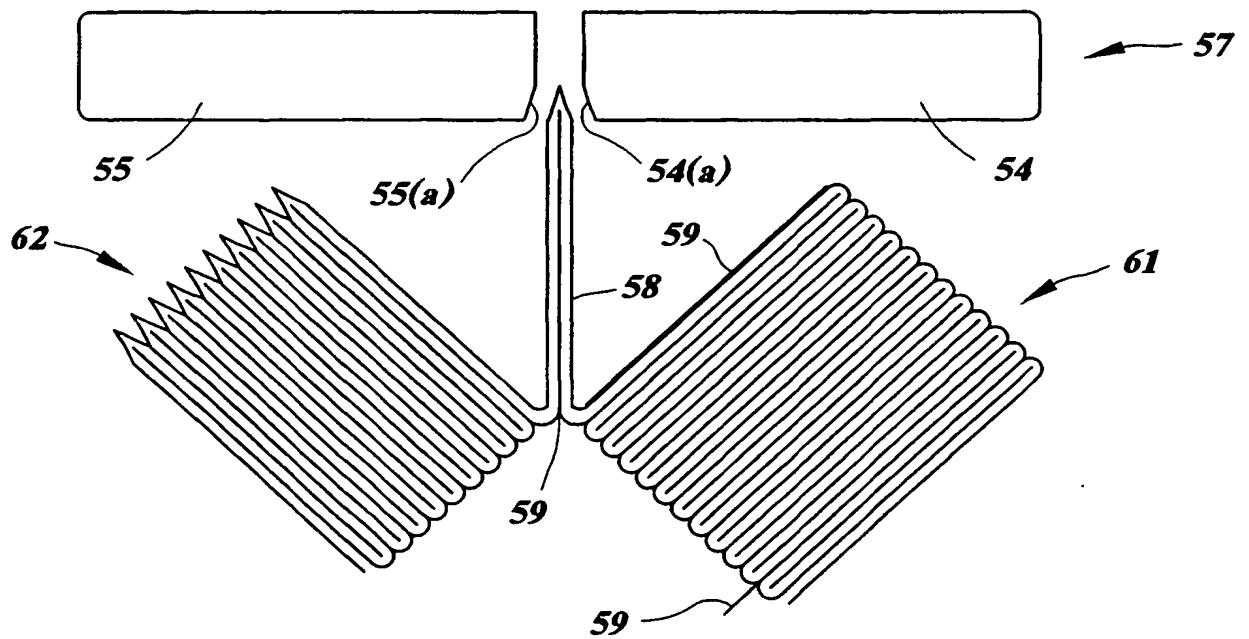
3/11**FIG. 3**

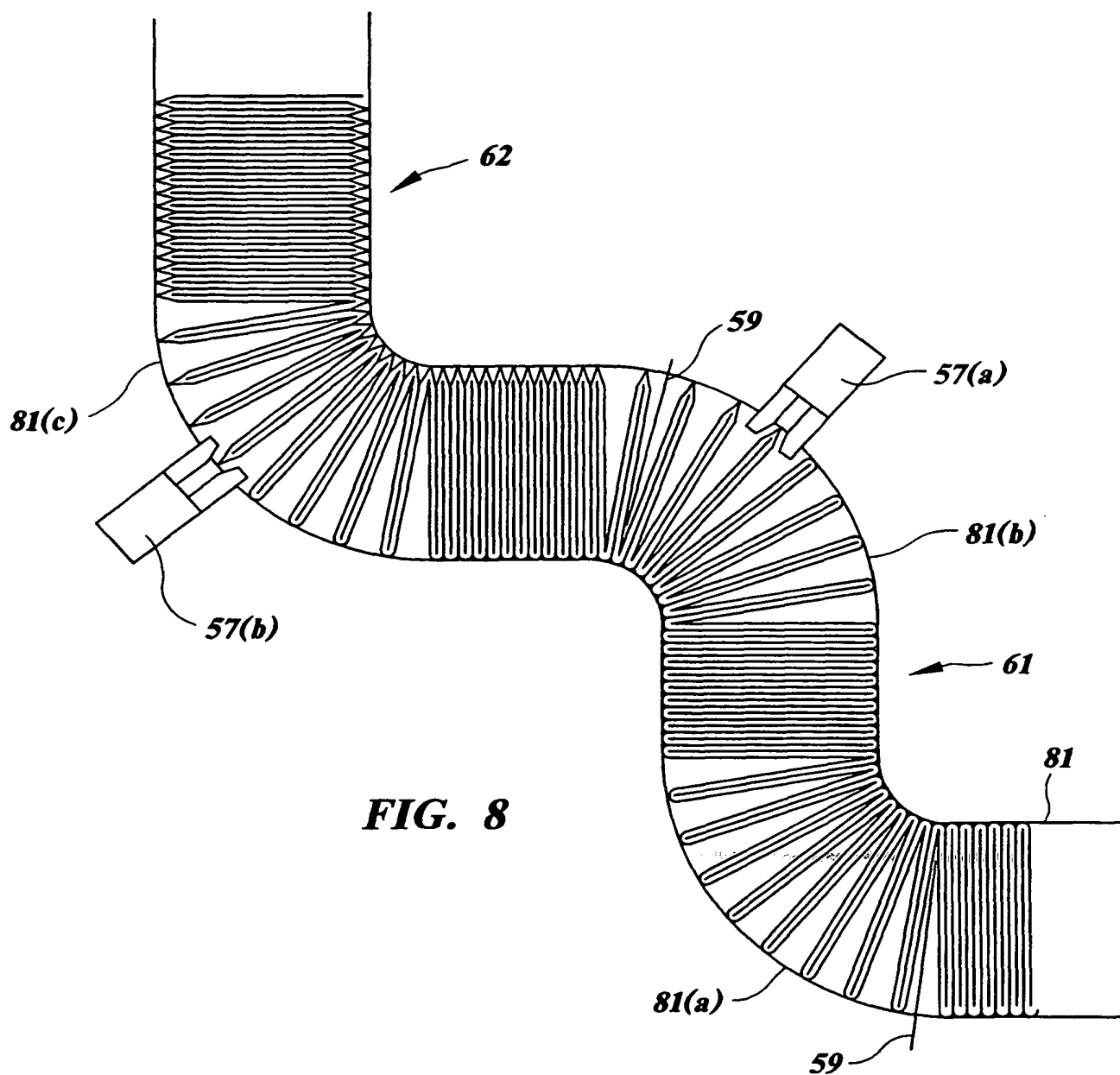
4/11**FIG. 4(a)****FIG. 4(b)**

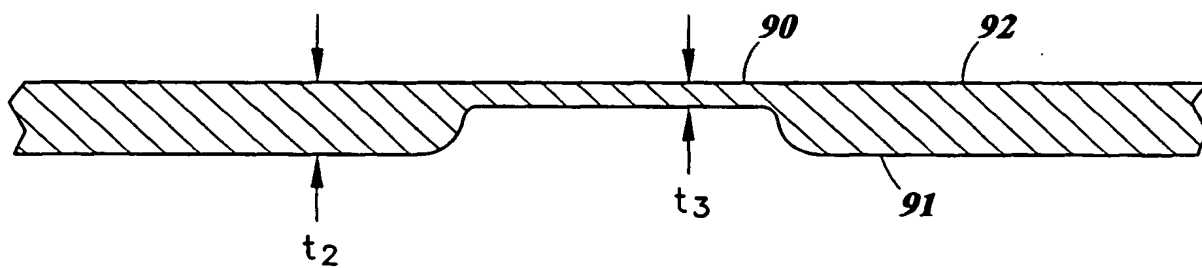
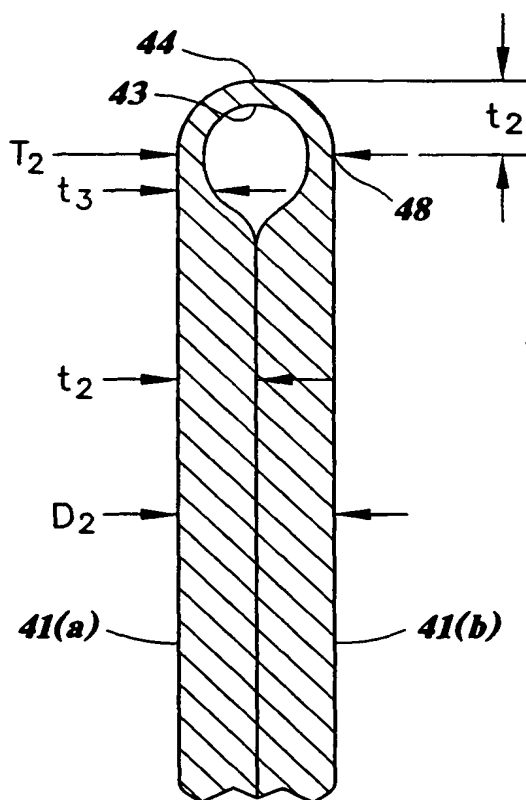
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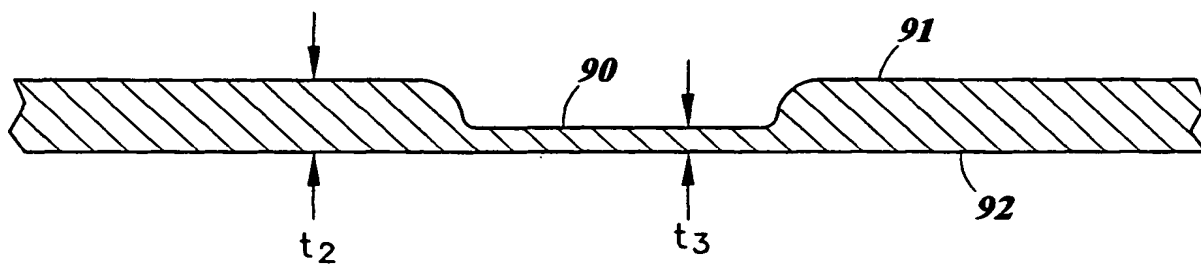
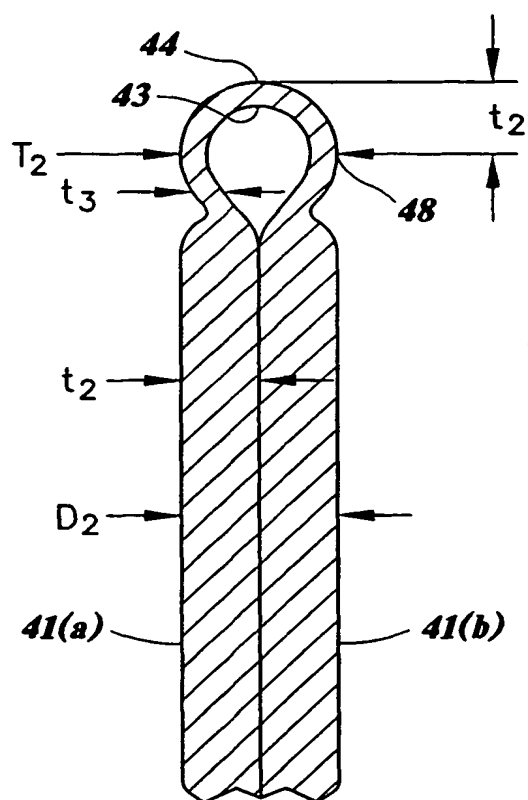
6/11**FIG. 5****FIG. 6**

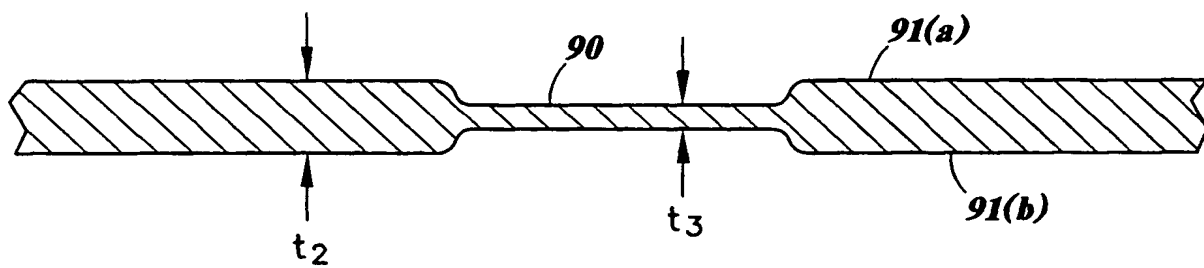
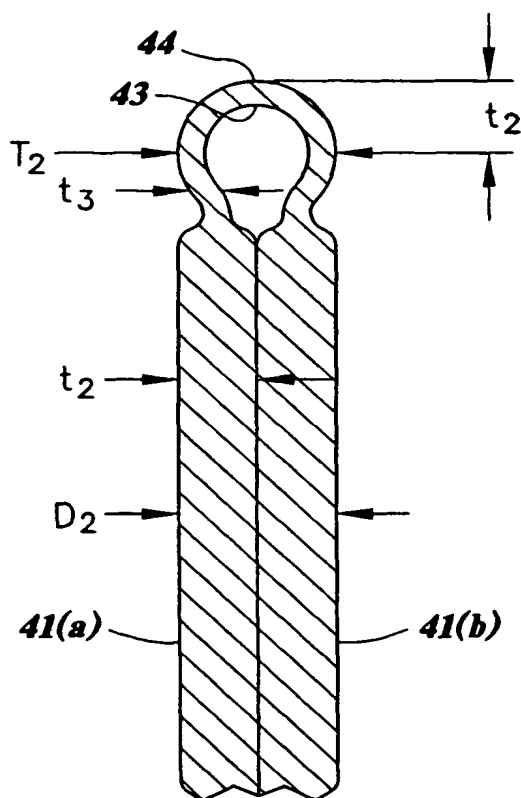
7/11

**FIG. 7**

8/11**FIG. 8**

9/11**FIG. 9(a)****FIG. 9(b)**

10/11**FIG. 9(c)****FIG. 9(d)**

11/11**FIG. 9(e)****FIG. 9(f)**

INTERNATIONAL SEARCH REPORT

In national Application No

PCT/US 99/14439

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B01D46/52

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
X	US 5 702 801 A (CHIEN JUNG-FU) 30 December 1997 (1997-12-30) column 2, line 11; figures 9,17	1-11,13, 14,16
X	GB 2 225 543 A (ENVAIR) 6 June 1990 (1990-06-06) figure 2	1,2, 8-11,13
X	EP 0 692 294 A (NIPPON DENSO CO) 17 January 1996 (1996-01-17) page 4, line 19-22; figure 2	1-3,6-13



Further documents are listed in the continuation of box C



Patent family members are listed in annex

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 99/14439

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5702801 A	30-12-1997	US 5558924 A DE 69312763 D DE 69312763 T EP 0558205 A ES 2109431 T	24-09-1996 11-09-1997 12-03-1998 01-09-1993 16-01-1998
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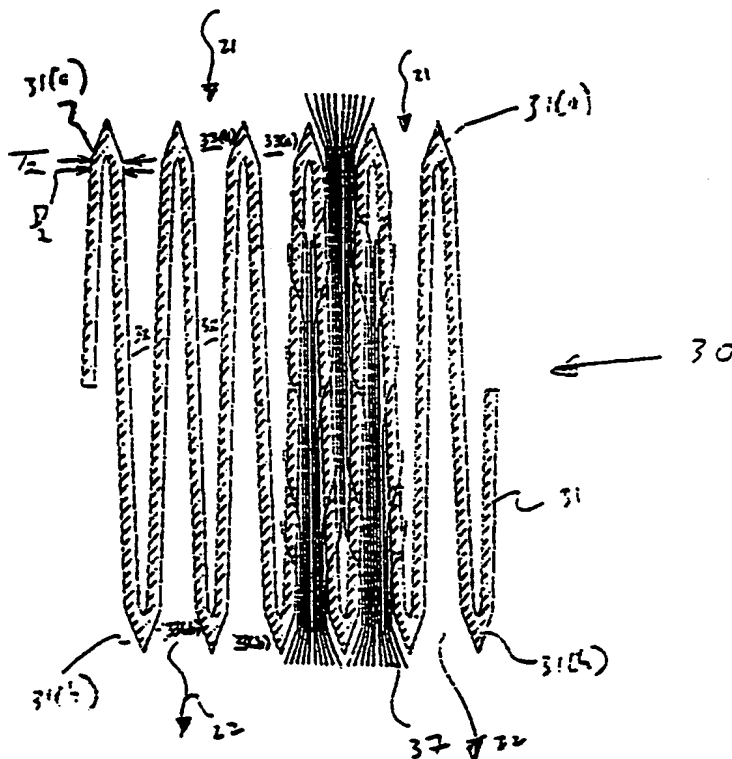
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : B01D 46/52		A1	(11) International Publication Number: WO 00/00270
			(43) International Publication Date: 6 January 2000 (06.01.00)
(21) International Application Number: PCT/US99/14439 (22) International Filing Date: 29 June 1999 (29.06.99) (30) Priority Data: 60/091,042 29 June 1998 (29.06.98) US (71) Applicant (for all designated States except US): PALL CORPORATION [US/US]; 2200 Northern Boulevard, East Hills, NY 11548-1209 (US). (72) Inventors; and (75) Inventors/Applicants (for US only): WELCH, Thomas, C., Jr. [US/US]; 11 Lora Lane, Homer, NY 13077 (US). VERSCHNEIDER, Joseph [US/US]; Apartment 2N, 42 North Church Street, Cortland, NY 13045 (US). MILLER, John, D. [US/US]; 511 Kline Road, Ithaca, NY 14850 (US). (74) Agent: BELZ, John, M.; Leydig, Voit & Mayer, Ltd., Suite 300, 700 Thirteenth Street, N.W., Washington, DC 20005 (US).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>	

(54) Title: PLEATED FILTER AND A METHOD FOR MAKING THE SAME

(57) Abstract

Filters having non-bulbous pleat tip regions are disclosed along with processes and apparatus for making filters having non-bulbous pleat tip regions.



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PLEATED FILTER AND A METHOD FOR MAKING THE SAME

This application claims the priority of U.S. Provisional Patent Application No. 60/091,042, filed June 29, 1998, which is incorporated by reference in its entirety.

Background of the Invention

Fluid filtration, e.g., gas filtration or liquid filtration, is important in a wide variety of industrial processes, including in the manufacture of electronic devices. Air filtration, for example, is very important in manufacturing semiconductors. Semiconductors are manufactured in ultra-clean manufacturing facilities called "clean rooms". Unlike ordinary rooms, clean rooms are substantially free of particulate contaminants. Typical clean rooms can have less than 100 particles per cubic foot. If the air in a clean room is not substantially free of particulate contaminants, the particulate contaminants in the air can decrease semiconductor yields. For example, contaminants in the air of a clean room can deposit on an unprotected circuit of a semiconductor potentially short-circuiting and damaging the semiconductor. Damaged semiconductors are usually reworked or discarded as scrap.

Conventional air filters for clean rooms use filter media made from glass fibers. While glass fiber filter media can be capable of filtering particulate contaminants from an incoming air stream, glass fiber filter media itself can produce contaminants which can lower semiconductor yields. For example, conventional glass fiber filter media contains borosilicate glass, which can produce boron-containing contaminants. Fluorine gas (e.g., released from etching processes) and water in the air of a clean room can combine to react with the borosilicate glass fibers in the filter media and produce airborne, boron-containing contaminants such as silicon boride. These airborne, boron-containing contaminants can decrease semiconductor yields by settling on the semiconductors during processing. Silicon boride contaminants, for example, can degrade the electrical properties of semiconductors

and consequently decrease semiconductor yields. Since the air in a clean room must be filtered, most semiconductor process engineers simply accept airborne boron contamination as inevitable and employ additional process steps to compensate for the contamination. For instance, a buffered HF (hydrogen fluoride) clean-and-etch step can be added to remove some
5 of the boron contamination from the surface of a semiconductor.

Filtering the clean room air with a filter medium substantially free of boron may reduce the amount of boron contaminants in a clean room. However, conventional filters incorporating substantially boron-free filter media, such as polymeric filter media, may not be advantageous. A filter medium is typically pleated in order to increase the filter surface area
10 for a predefined envelope (e.g., a space defined by a housing or frame). When a polymeric filter medium (e.g., a filter medium formed from a polymeric material such as polymeric fibers) is pleated, the medium can have a tendency to "spring back" in the pleat tip region, resulting in a pleat tip region with a conventional bulbous shape. A pleated filter medium having conventional bulbous-shaped pleat tip regions can disadvantageously have a low
15 number of pleats per unit of length, exhibit high differential pressure when filtering a fluid and/or have a diminished structural stability. Further, due to the "spring back" properties of many polymeric filter media, such media can be difficult to pleat.

Figure 1 shows a portion of a filter element 20, which includes a pleated filter medium 11 having a plurality of upstream conventional bulbous-shaped pleat tip regions
20 11(a) and downstream conventional bulbous-shaped pleat tip regions 11(b). A contaminated fluid stream 21 flowing towards the upstream spaces 12(a) between the pleats of the pleated filter medium 11 may be impeded by the upstream conventional bulbous-shaped pleat tip regions 11(a). The spaces 12(a) between the adjacent upstream conventional bulbous-shaped pleat tip regions 11(a) are relatively narrow and may bottleneck the flow of the contaminated
25 fluid stream 21 into the pleated filter medium 11. Eventually, the contaminated fluid stream

21 passes through the pleated filter medium 11 forming a purified fluid stream 22. The purified fluid stream 22 can then flow in the downstream spaces 12(b) between the downstream pleat tip regions 11(b) of the pleated filter medium 11, before exiting the pleated filter medium 11. As the purified fluid stream 22 flows downstream, the downstream conventional bulbous-shaped pleat tip regions 11(b) can impede the flow of the purified fluid stream 22 out of the pleated filter medium 11. The spaces 12(b) between the adjacent downstream conventional bulbous-shaped pleat tip regions 11(b) are relatively narrow, and may bottleneck the flow of the purified fluid stream 22 out the pleated filter medium 11. The fluid stream lines 17 through the filter element show the bottlenecks at the upstream and downstream pleat tip regions. These bottlenecks greatly increase the pressure drop across the filter element. Consequently, greater upstream pressure may be required to force the contaminated fluid stream 21 past the upstream conventional bulbous-shaped pleat tip regions 11(a) and the purified fluid stream 22 past the downstream conventional bulbous-shaped pleat tip regions 11(b). Unfortunately, greater upstream fluid pressures require greater energy to compress the contaminated fluid stream.

Summary of the Invention

One aspect of the invention is directed to a filter element, filter pack or filter composite comprising a pleated filter medium including pleats having a pleat tip region with a predetermined shape.

Another aspect of the invention is directed to a filter comprising a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region. A thickness of the pleat tip region at a point spaced about one to four pleat leg thicknesses from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness.

Another aspect of the invention is directed to a filter comprising a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region. A thickness of the pleat tip region at a point spaced about one to four pleat leg thicknesses from the end of the pleat is less than or equal to a distance between corresponding points on opposing outer surfaces of the pleat legs.

Another aspect of the invention is directed to a filter comprising a pleated structure having a plurality of pleats and more than one layer. At least one of the pleats having a reformed pleat tip region.

Another aspect of the invention is directed to a filter comprising a pleated structure having a plurality of pleats and a pair of pleat legs, at least one of the pleats having a reformed pleat tip region and contacting pleat legs.

Another aspect of the invention is directed to a filter comprising a plurality of pleats, at least one pleat including a pleat tip region having contacting inner surfaces.

Another aspect of the invention is directed to a filter comprising a pleated porous sheet having a polymeric material and a plurality of pleats. At least one pleat includes a pair of pleat legs and a pleat tip region, the pleat tip region including a pre-scored region.

Another aspect of the invention is directed to a method of making a filter comprising: forming a plurality of pleats having pleat tip regions; and applying pressure to opposing outer surfaces of at least one pleat tip region.

Another aspect of the invention is directed to a method of making a filter comprising: forming a plurality of pleats free of bulbous pleat tip regions.

Another aspect of the invention is directed to a method of making a filter comprising: forming a plurality of pleats wherein a thickness of each pleat tip region at eight points spaced about 1 to about 4 pleat leg thicknesses from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness.

Another aspect of the invention is directed to a method of making a filter comprising: forming a plurality of pleats, wherein a thickness of the pleat tip region at eight points spaced about one to about four pleat leg thicknesses from the end of the pleat tip region is less than or equal to a distance between corresponding points on opposing outer surfaces of the pleat leg.

Another aspect of the invention is directed to a method of making a filter comprising: scoring a porous sheet including a polymeric material; and pleating the porous sheet.

Another aspect of the invention is directed to an apparatus comprising one or more dies arranged to reform a pleat tip region of a pleat.

While the filtration of clean room air has been discussed in detail, embodiments of the invention are not limited to filtering clean room air. For example, embodiments of the invention can relate to cabin air filters, which can be used to filter the air of an aircraft cabin, as well as flat and cylindrical pleated filters for liquid service. For example, embodiments of the invention can also be used to filter liquids such as fuel. Further, embodiments of the invention relate to pleated filters useful in dead end filtration, for example, where process fluid flows radially through a cylindrical pleated filter pack, or in cross flow filtration, for example, where process fluid flows axially along a cylindrical pleated filter pack.

Embodiments of the invention can provide for a number of advantages. For example, embodiments of the invention can provide for reduced differential pressure across the filter or filter medium, improved filtration properties, improved flow properties through or along the filter, improved structural properties and/or reduced contaminant production. The systems and methods according to embodiments of the invention can provide for efficient and low cost manufacture of filters and filter media.

Brief Description of the Drawings

Figure 1 illustrates a side view of a filter element including a filter medium having conventional bulbous-shaped pleat tip regions.

Figures 2(a) and 2(b) illustrate cross-sections of pleats.

Figure 3 illustrates a side view of a filter element of an embodiment of the invention.

Figures 4(a)-4(c) show cross-sectional views of pleats.

Figures 5-8 show methods and systems.

Figures 9(a)-9(f) show cross-sectional views of pre-scored sheets and pleats.

Detailed Description

Pleated filter elements embodying the invention may be configured in a wide variety of ways. For example, the filter element may be configured as a parallelepiped or a cylinder. The pleats of the filter element may include generally parallel or non-parallel legs which are straight or curved and which contact one another or are spaced from one another. United States Patents No. 5,098,767; No. 5,252,207; and No. 5,543,047 and United States Patent Application No. 60/099,663 disclose many of these features and are incorporated herein by reference.

In some pleated filter elements embodying the invention, one or more, and preferably all, of the pleats include a pair of pleat legs and a pleat tip region having a predetermined, non-bulbous shape, e.g., a tapered, squared, or rounded shape. A pleat tip region can include any suitable portion near the crest and/or root of a pleat including an apex of the pleat. For example, a pleat tip region may extend any suitable length along a pleat in the vicinity of an apex of the pleat. In the pleat tip regions, the thickness of the pleat tip region at a point in the vicinity of about one to about four pleat leg thicknesses from the end of the pleat tip region can be less than about twice the thickness of a corresponding pleat leg. Other embodiments can be directed to a filter including a pleated porous sheet having a plurality of pleats, at least one

pleat comprising a pair of pleat legs and a pleat tip region. A thickness of the sheet at the pleat tip region is less than one pleat leg thickness, and the pleat legs may contact one another. The term "sheet" includes any suitable structure having one or more layers. For example, a "sheet" can include a filter medium having one, two, three, or more layers. In
5 another example, a "sheet" can include a filter composite having several layers in addition to a filter medium, including one or more drainage layers and/or a cushioning layer.

Each of the Figures including Figs. 2(a) and 2(b) show pleats, and each pleat includes two pleat legs joined at a pleat tip region including an apex of the pleat. Each leg is illustrated as a single layer structure but it is representative of one or more layers and is correspondingly
10 described as a "filter medium" or a "filter composite". Thus, this aspect of the drawings is merely representational. As explained above, a filter medium can have one, two, three, or more layers, and a filter composite can comprise several layers in addition to a filter medium, including one or more drainage layers and/or a cushioning layer. Embodiments of the invention are particularly advantageous for a filter medium or a filter composite having a porous
15 polymeric fibrous medium, such as a polymeric fibrous depth filter medium. Such a medium is very springy and resists the formation of a sharp fold in conventional corrugators. Consequently, conventional filters having fibrous polymeric media have conventional bulbous pleat tip regions, as shown in Figure 2(a).

The pleat shown in Figure 2(a) includes two pleat legs 8(a), 8(b) and a pleat tip region
20 11(c) with a conventional bulbous shape. The conventional bulbous-shaped pleat tip region 11(c) can naturally result from folding a sheet of filter medium or filter composite upon itself. The thickness of the conventional bulbous-shaped pleat tip region 11(c) is greater than the thickness of other portions of the pleat. For example, the thickness T of the pleat tip region is greater than a distance D_1 between corresponding points on opposing outer surfaces of the
25 pleat legs 8(a), 8(b). Further, the thickness T of the pleat tip region in the vicinity from about

one to about four pleat leg thicknesses from the end of the pleat is greater than twice the thickness t_2 of a pleat leg. Consequently, the packing density (e.g., the number of pleats per inch) of similarly shaped adjacent pleats is limited by the thickness the pleat tip regions of the pleats. Also, greater upstream fluid pressures are required to filter a contaminated fluid stream with a pleated filter medium or composite having conventional bulbous-shaped pleat tip regions. As explained previously, the narrow flow passages between adjacent conventional bulbous-shaped pleat tip regions may bottleneck the flow of the contaminated and purified fluid streams into and out of the pleats of the filter medium or composite. Further, the structural stability of the pleat could be improved.

In contrast, Figure 2(b) illustrates a pleat, for example, a pleat of filter medium or filter composite according to an embodiment of the invention. Figure 2(b) shows a pleat of a polymeric medium, such as a fibrous polymeric medium, having a non-bulbous shaped pleat tip region 11(d) and two pleat legs 9(a), 9(b) disposed generally parallel to one another. The pleat tip region 11(d) may be tapered and/or may have improved structural stability. The thickness of the pleat tip region 11(d) is less than the thickness of other portions of the pleat. For example, the thickness of the pleat tip region, T_1 , is less than a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 9(a), 9(b). Further, the thickness of the pleat tip region at a point in the vicinity of about one to about four pleat leg thicknesses t_2 , preferably about one to two pleat leg thicknesses t_2 , and more preferably about one pleat leg thickness t_2 , from the end of the pleat tip region is less than or equal to about twice the thickness t_2 of a corresponding pleat leg. Because the pleat shown in Figure 2(b) has a narrowly confined pleat tip region, the proximity of similarly shaped adjacent pleats is not limited by thickness of the pleat tip regions. Consequently, the pleats of the pleated filter medium or composite having non-bulbous shaped pleat tip regions can be packed closer

together than a corresponding medium or composite having conventional bulbous-shaped pleat tip regions.

Closely packed pleats or high packing efficiencies can be advantageous. In embodiments of the invention, the number of pleats per length may be increased by up to 80% to 100% or more. For example, a pleated filter medium or filter composite having conventional bulbous-shaped pleat tip regions and an average pleat leg thickness of about 30/1000 inch may have a maximum of 6 or 7 pleats per inch. In contrast, a pleated filter medium or composite having the same pleat leg thickness, but with pleat tip regions in accordance with embodiments of the invention, can have between about 10 and 12 pleats per inch. Advantageously, a filter element including a pleated filter medium or filter composite having closely packed pleats can have improved filtration properties, because the effective filtration area for a predetermined envelope (e.g., a space defined by a housing) can be increased.

The advantage of having closely packed pleats is even more evident when such pleats are used in conjunction with cylindrical pleated filters where the number of pleats is typically inversely proportional to two times the thickness of the pleated material (e.g., the thickness corresponding to a single pleat of material). By providing (e.g., by reforming) a pleated sheet with pleat tip regions with a thickness of less than about two times the thickness at a pleat leg, the number of pleats and thus the effective filter area for a given envelope can be increased proportionally. For instance, in embodiments of the invention, increases in the number of pleats and/or effective filter area can be greater than or equal to about 15% in comparison with conventional pleated structures.

Embodiments of the invention can provide for other advantages. A pleated filter medium or filter composite without bulbous shaped pleat tip regions can provide improved flow properties through or along the filter. For example, eliminating the bulbous shaped pleat

tip regions from a cross flow filter embodying the invention eliminates large channels through which the process fluid would otherwise preferentially flow. This provides more even contact between the process fluid and the entire filter medium and enhances residence time within the filter. On the permeate side of the filter eliminating the bulbous shaped pleat tip regions eliminates preferential flow of permeate into these bulbous-shaped channels, providing a more even flow through the filter medium.

A pleated filter medium or filter composite without bulbous shaped pleat tip regions can also provide for lower differential pressure across the medium or composite. For example, a pleated filter medium or filter composite having non-bulbous shaped pleat tip regions can have wider and/or more uniform fluid flow passages between adjacent pleats than a pleated filter medium or filter composite having conventional bulbous-shaped pleat tip regions. These wider and/or more uniform flow passages permit fluid streams to flow into and past the pleated filter medium or composite with greater ease and with less upstream fluid pressure. This advantage can be more clearly illustrated with reference to Figure 3.

Figure 3 shows a portion of a pleated filter element 30 including a pleated filter medium or filter composite 31. The pleated filter medium or filter composite 31 includes a plurality of upstream and downstream pleat tip regions 31(a), 31(b) embodying the invention. Each of the pleat tip regions 31(a), 31(b) may include a maximum thickness T_2 which can be less than or equal to a minimum distance D_2 between opposing outer surfaces of corresponding pleat legs. Further, the thickness of each pleat tip region at a point in the vicinity of about one to about four pleat leg thicknesses, preferably about one to two pleat leg thicknesses, and more preferably about one pleat leg thickness from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness. Because the upstream pleat tip regions 31(a) of the pleated filter medium 31 are substantially free of a conventional bulbous-shape, a contaminated fluid stream 21 can flow relatively unimpeded into the

upstream spaces 33(a) between adjacent upstream pleat tip regions 31(a), and into the spaces 32 between the pleats of the pleated filter medium 31. The contaminated fluid stream 21 then passes through the pleated filter medium 31 forming a purified fluid stream 22. The purified fluid stream 22 can then flow downstream out of the pleated filter medium 31 relatively unimpeded in the downstream spaces 33(b) between adjacent downstream pleat tip regions 31(b). Less upstream pressure and energy are required to filter a contaminated fluid with the filter element 30 shown in Figure 3 than the filter element 20 shown in Figure 1. This is because the filter medium 31 in Figure 3 does not have conventional bulbous-shaped pleat tip regions which impede the flow of the contaminated and purified fluid streams 21, 22 between the pleat tip regions 31(a), 31(b). As illustrated by the fluid stream lines 37, the flow of the contaminated fluid stream 21 and the purified fluid stream 22 is not substantially impeded in the spaces between the pleat tip regions 31(a), 31(b).

Embodiments of the invention can have pleat tip regions with any suitable shape. For example, the inner surfaces of the pleat tip regions may have any suitable shape, including a flat, pointed, tapered, squared, rounded, triangular or irregular shape. The outer surfaces of the pleat tip regions may also have any suitable shape, such as a tapered, pointed, flat, rounded, oblong, squared, triangular, or irregular shape. Regardless of the particular pleat tip region shape, the thickness of a pleat tip region is preferably less than about two times the thickness of a pleat leg and/or is less than a distance between corresponding points on opposing outer surfaces of the pleat legs.

If the shape of the outer and/or inner surface of the pleat tip region is tapered, the taper may be either gradual or intermittent (e.g., stepped). Tapered pleat tip regions advantageously do not substantially impede the flow of an approaching or passing fluid stream. As explained previously, adjusting the shape of the pleat tip regions of a pleated

filter medium or composite can reduce the differential pressure across the medium or composite and can also increase the packing efficiency of the pleats.

Figure 4(a) shows a pleat of filter medium or filter composite in accordance with another embodiment of the invention. The pleat has an inside and outside surface, and includes two pleat legs 41(a), 41(b), as well as a pleat tip region with an outer end 44. Inner surfaces of the pleat can face and contact each other in or near the vicinity of the pleat tip region. A spacer 45 may lie between the substantially parallel pleat legs 41(a), 41(b), but preferably does not disrupt the contact between the contacting and facing surfaces of the pleat at the pleat tip region. Each of the pleat legs 41(a), 41(b) has a thickness t_2 . At a point 48 spaced a distance in the range from about t_2 to about $4t_2$, preferably about t_2 to $2t_2$, and more preferably about t_2 (i.e., a distance equal to about the thickness of a pleat leg) from the end 44 of the pleat tip region, the thickness of the pleat tip region is no greater than about twice the thickness of a pleat leg 41(a), 41(b), or is less than or equal to about two times t_2 . Thus, the thickness T_2 may be less than or substantially equal to any rational number R times the thickness of a pleat leg where R is less than about two and greater than about zero (e.g., 1.95, 1.5, 1.0). The thickness T_2 at this point 48 is also less than a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 41(a), 41(b). In this embodiment, the point 48 spaced a distance t_2 from the end of the pleat tip region substantially corresponds to a point 43 on the inside surface at the apex 49 of the pleat and opposite the end 44 of the pleat.

As illustrated by the pleat shown in Figure 4(a), a spacer comprising, for example, a drainage layer may be optionally present within the pleat. For example, a spacer may be positioned between adjacent pleat legs, partially or completely filling the space between the pleat legs and/or the facing surfaces at the pleat tip region. The spacer may extend partially or completely into the pleat tip region, or it may terminate short of the pleat tip region. While

a drainage layer has been described as a spacer for illustrative purposes, the spacer may include such structures as adhesive beads, porous strips, or any combination of structures suitable for spacing the facing surfaces of a pleat.

Also, as illustrated by the pleat shown in Figure 4(a), facing inner surfaces of the pleat preferably contact each other at the pleat tip region. By keeping the facing inner surfaces the pleat in contact at a pleat tip region, the pleat tip region is less likely to bulge into a conventional bulbous shape and is more stable. In some embodiments, facing portions of a pleat tip region can be bonded together, thus preventing the pleat tip region from forming a conventional bulbous shape. This adherence and bonding can be facilitated by any suitable method. For example, the facing surfaces of a pleat tip region can be bonded together by contacting and heat bonding the facing surfaces together. Other exemplary methods for contacting and/or bonding facing surfaces at the pleat tip region are described below.

Figure 4(b) shows another pleat in accordance with an embodiment of the invention. The pleat shown in Figure 4(b) includes inner and outer surfaces, two pleat legs 41(a), 41(b) forming a general V-shape, and a pleat tip region including an end 44. Each of the pleat legs 41(a), 41(b) has a thickness t_2 . At a point 48 spaced a distance about t_2 (i.e., about equal to a thickness of a pleat leg) from the end 44 of the pleat, the thickness of the pleat tip region is T_2 . The thickness T_2 is less than a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 41(a), 41(b), and is less than or substantially equal to twice the pleat leg thickness ($2t_2$). Like the embodiment illustrated in Figure 4(a), the point 48 spaced a distance about t_2 from the end 44 substantially corresponds to a point 43 on the inside surface of the pleat at the apex 49.

Figure 4(c) illustrates a pleat of a porous sheet of a filter medium or filter composite according to another embodiment of the invention. The pleat shown in Figure 4(c) includes inner and outer surfaces, two pleat legs 41(a), 41(b), and a pleat tip region with an end 44.

Each of the pleat legs 41(a), 41(b) has a thickness t_2 , while a portion of the pleat at the pleat tip region can have a thickness equal to t_3 , which is less than the pleat leg thickness t_2 . The thickness at the pleat tip region (e.g., t_3) can be less than or substantially equal to any rational number R times the thickness of a pleat leg, where R is less than or equal to 1, but greater than zero (e.g., 0.99, 0.9, 0.75, 0.5, 0.33, 0.2). This thickness (e.g., t_3) can be measured at a point spaced inwardly from the end 44 of the pleat or a point 43 opposite the end 44 (e.g., a distance between about one to about four pleat leg thicknesses from the end 44 of the pleat).

The thickness of the porous sheet can be reduced prior to, concurrent with, or after the formation of the pleats. In one example, a porous sheet of filter medium or filter composite can be pre-scored with a plurality of substantially parallel lines or stripes, so that the scored lines substantially correspond to the later formed apexes and/or a portion of all of the pleat tip region of the resulting pleated structure. The scoring process can reduce the thickness of the filter medium or the filter composite at the pleat tip region of the pleat, e.g., by pressing score lines into the medium or composite with a pressure applicator such as a roller and/or heater. Scoring processes in accordance with embodiments of the invention are discussed in more detail below. Alternatively, the thickness of the sheet can be reduced concurrent with the formation of the pleats. In another example, a porous sheet can be pleated by conforming the porous sheet around one or more heated or non-heated mandrels or dies. Pressure and/or heat from the mandrel or dies can be applied to the outer and/or inner surface of the sheet to reduce the thickness of the sheet at the pleat tip region (e.g., by melting and/or compression of the sheet) while the pleat is being formed.

Again with reference to Figure 4(c), at a point 48 spaced a distance about t_2 (i.e., about equal to the thickness of a pleat leg) from the end 44 of the pleat, the thickness of the pleat tip region is T_2 . The thickness T_2 is less than or substantially equal to about twice the thickness of one of the pleat legs 41(a), 41(b) or about two times t_2 . The thickness T_2 is also

less than a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 41(a), 41(b). Unlike the embodiments illustrated in Figures 4(a) and 4(b), the point 48 spaced a distance about t_2 from the end 44 of the pleat does not substantially correspond to a point 43 on the inside surface of the pleat at the apex 49 and opposite the end 44 of the pleat.

5 In addition, unlike the embodiment shown in Figure 4(a), facing surfaces of the pleat at the pleat tip region do not contact each other. Although facing surfaces of the pleat at the pleat tip region do not contact each other in the illustrated embodiment, the shape of the pleat tip region remains substantially non-bulbous. Alternatively, facing surfaces of the pleat tip region (e.g., including the point 43 opposite the end 44 of the pleat) may contact each other
10 to, e.g., improve the stability of the pleat tip region, and/or reduce the likelihood that pleat tip region will form into conventional bulbous shape. As explained previously, a pleated filter element without conventional bulbous shaped pleat tip regions can advantageously provide the filter element with a higher packing efficiency and a reduced pressure differential across the filter element.

15 In some embodiments, a porous sheet having one or more layers of filter medium or filter composite may be pre-scored with substantially parallel lines having any suitable width, prior to pleating the sheet. The scoring of the sheet may occur in any suitable manner, including heating, scribing, melting, embossing and/or pressing. The scoring of the sheet can be performed with any suitable device, including a rotary pleater, edge knife, roller, die, etc.
20 Preferably, the scoring of the sheet forms pre-scored regions of reduced thickness relative to other portions of the sheet. For example, a porous polymeric sheet of filter medium or composite can be scored by pressing substantially parallel lines in the sheet with one or more heated or non-heated pressure applicators (e.g., rollers, blades). Heat and/or pressure from the pressure applicator(s) can melt and/or reduce the thickness of the sheet, thus forming pre-
25 scored regions. This pre-scored sheet can then be pleated. For example, the scored sheet can

be formed into a pleated filter medium or composite by folding the sheet multiple times in a zig-zag manner so that pre-scores on the sheet substantially correspond with the apexes of the resulting pleated filter medium or filter composite.

In one embodiment, a sheet of filter medium or filter composite may be scored to
5 create a discontinuous surface on one side and a continuous surface on the other. The sheet can then be pleated so that the continuous surface side of the sheet forms the end of the pleat. This can be more clearly illustrated in Figures 9(a) and (b). Figure 9(a) illustrates a sheet of filter medium or filter composite having a thickness t_2 at a non-scored region and a thickness t_3 at a pre-scored region 90. The sheet includes a discontinuous surface 91 and a continuous
10 surface 92. The sheet can then be pleated so that side having the continuous surface 90 forms the end 44 of the pleat. The resulting pleat is shown in Figure 9(b). The pleat shown in Figure 9(b) is similar in shape to the pleat shown in Figure 4(c), except that the pleat in Figure 9(b) shows contacting pleat legs. Advantageously, by contacting the legs of the pleats in a pleated structure, the number of pleats per length can be increased, thus increasing the
15 filter capacity of the pleated structure.

In another embodiment, the pre-scored sheet can then be pleated so that the discontinuous surface side of the sheet forms the end of the pleat. This can be more clearly illustrated in Figures 9(c) and 9(d). Figure 9(c) illustrates a sheet of filter medium or filter composite having a thickness t_2 at a non-scored region and a thickness t_3 at a pre-scored
20 region 90. The sheet includes a discontinuous surface 91 and a continuous surface 92. The sheet can then be pleated so that the discontinuous surface side 90 of the sheet forms the end of the pleat 44. The resulting pleat is shown in Figure 9(d).

The pleats shown in Figures 9(b) and 9(d) each include inner and outer surfaces, two pleat legs 41(a), 41(b), and a pleat tip region with an end 44. Each of the pleat legs 41(a),
25 41(b) has a thickness t_2 . The thickness of the sheet at the pleat tip region (e.g., t_3) can be less

than or substantially equal to any rational number R times the thickness of a pleat leg, where R is less than or equal to 1, but greater than zero (e.g., 0.99, 0.9, 0.75, 0.5, 0.33, 0.2). This thickness (e.g., t_3) can be measured at a distance inward from the end 44 of the pleat or a point 43 opposite the end 44 of the pleat (e.g., between about one to about four pleat leg thicknesses from the end 44 of the pleat tip region). At a point 48 spaced about one pleat leg thickness t_2 from the end 44 of the pleat tip region, the thickness of the pleat tip region can be T_2 . This thickness, T_2 , can be less than or equal to a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 41(a), 41(b), and less than or equal to twice the pleat leg thickness ($2t_2$). The pleat tip region of the pleat shown in Figs. 9(b) and (d) can be structurally stable, thin, and easily formed.

Alternatively, the porous sheet can be pre-scored so that discontinuous surfaces are present on opposing sides of the sheet. This is more clearly illustrated with respect to Figures 9(e) and 9(f). Figure 9(e) illustrates a sheet of filter medium or filter composite having a thickness t_2 at a non-scored region and a thickness t_3 at a pre-scored region 90. The sheet includes a first discontinuous surface 91(a) on one side of the sheet and a second discontinuous surface 91(b) on the other side of the sheet. As shown in Figure 9(e), the discontinuities on opposing sides of the sheet can substantially correspond to each other, and can be formed by, e.g., scoring opposite sides of the sheet. Scoring opposite sides of the sheet may increase the stability of the pleat tip region by ensuring that the material at both sides of the sheet is sufficiently compressed. The sheet can then be pleated. The resulting pleat is shown in Figure 9(f).

The pleat shown in Figure 9(f) includes inner and outer surfaces, two pleat legs 41(a), 41(b), and a pleat tip region with an end 44. Each of the pleat legs 41(a), 41(b) has the thickness t_2 . The thickness of the sheet at the pleat tip region (e.g., t_3) can be less than or substantially equal to any rational number R times the thickness of a pleat leg, where R is less

than or equal to 1, but greater than zero (e.g., 0.99, 0.9, 0.75, 0.5, 0.33, 0.2). This thickness (e.g., t_3) can be measured at a distance inward from the end 44 of the pleat or a point 43 opposite the end 44 of the pleat (e.g., between about one to about four pleat leg thicknesses from the end 44 of the pleat tip region). At a point 48 spaced about one pleat leg thickness t_2 from the end 44 of the pleat tip region, the thickness of the pleat tip region can be T_2 . This thickness, T_2 , can be less than a distance D_2 between corresponding points on opposing outer surfaces of the pleat legs 41(a), 41(b), and less than twice the pleat leg thickness ($2t_2$).

Pre-scoring a porous sheet and then pleating the porous sheet can be advantageous. For example, pre-scoring a porous sheet before pleating can impart added stability to the subsequently formed pleat tip region, and can make the pleating process easier by, e.g., providing easily identifiable and foldable regions on the porous sheet. In particular, such a process can be especially suitable for forming a stable, pleated polymeric filter such as a pleated fluoropolymeric filter. For example, a somewhat springy porous sheet of filter medium or filter composite can be easily pleated by, e.g., providing the sheet with pre-scored regions having a reduced thickness and then pleating the sheet along the pre-scored regions.

However, in a preferred embodiment, the pleat tip region is reformed rather than pre-scored or in addition to being pre-scored. For example, a filter medium or filter composite can be corrugated in a conventional corrugator, forming one or more pleats with pleat tip regions. Preferably, one or more, and more preferably all, of the pleat tip regions, including the entire region or continuous or discontinuous portions of each pleat tip region, thereafter may be reformed to ensure the pleat tip regions do not have a conventional bulbous shape.

If discontinuous portions of the pleat tip region are reformed, the end of the pleat tip region may or may not be reformed. For example, a portion of the pleat tip region spaced from the end of the pleat, but not including the end of the pleat, can be reformed to ensure that the pleat tip region (e.g., as a whole) does not have a conventional bulbous shape. In one

illustrative example, facing inner surfaces of the pleat tip region spaced from the end of the pleat, but not including the end of the pleat, can bond together by any suitable method (heat, pressure, adhesive, etc.), thus ensuring that the pleat tip region does not form a conventional bulbous shape and/or does not extend beyond corresponding points on opposing outer
5 surfaces of the pleat legs of the pleat. The portion of the pleat tip region including the bonded region can be spaced one to four pleat leg thicknesses from the end of the pleat tip region and can have a thickness less than about twice the pleat leg thickness.

Reforming methods may include any method which may alter the shape, the composition and/or the internal or external structure of a pleat tip region of a pleat to set the
10 pleat tip region in a non-bulbous shape. Reforming methods may include the application of pressure and/or heat to the pleat tip regions by, e.g., molding, squeezing, crushing, welding, pressing, melting, softening, heating, or any combination of these procedures. Another reforming method may be molding a pleat tip region with pressure, alone or in combination with sonic energy (e.g., ultrasonic) and/or electromagnetic energy (e.g., a radiant heater).

15 Any suitable pressure applicator (e.g., a pair of dies) can shape the pleat tip region by applying pressure to the pleat tip region, for example, on opposite sides of the outer surface of the pleat tip region. Consequently, the applied pressure can bond facing surfaces of the pleat tip region together by, e.g., causing the facing surfaces to intermix or commingle with one another. Preferably, ultrasonic heating and/or welding can be used to reform the pleat tip
20 regions, because ultrasonic heating and/or welding can be performed relatively quickly. Alternatively, the facing surfaces of a pleat at a pleat tip region can bond together by other processes including using an adhesive to bond facing surfaces of the pleat tip region together or solvent bonding facing surfaces of the pleat tip region together.

After the pleat tip regions of the pleats are reformed, the resulting pleat tip regions
25 may have a different composition, internal structure, and/or shape than before the reforming

process. For example, if a pleat tip region of a pleat is reformed with heat and pressure, the resulting pleat tip region may comprise not only a reformed shape, but also a fused or solid portion. The fused or solid portion may result from the softening, melting or liquification of the material of the filter medium in the pleat tip region during reformation. For example, a
5 pleat tip region of the pleat may include a porous sheet, such as a fibrous layer or a membrane, made of a low melting point material. The pleat tip region may be heated to reform the pleat tip region. The heat softens or melts the low melting point material, which partially or fully eliminates pores in the pleat tip region, thus creating a partially or fully solid structure in the pleat tip region. Pores in a pleat leg can be unaffected by the pleat tip region
10 reformation process. Alternatively, the pores in the pleat tip region may be unaffected by the application of heat and/or pressure. Illustrative methods and systems for reforming the pleat tip regions of pleated filter media are shown in Figures 5-8.

Figure 5 illustrates a shaping apparatus 57 for reforming the pleat tip regions of a corrugated structure such as a filter medium or filter composite, which has been previously
15 corrugated in any conventional manner. The shaping apparatus 57 can include two dies 54, 55, either or both of which may be movable. The dies 54(a), 55(a) are preferably moveable in directions generally perpendicular to the direction of the pleat having its pleat tip region reformed. For example, the dies 54(a), 55(a) may reform the pleat tip region by applying pressure and/or heat to opposing outer surfaces of the pleat tip-region. Each of the dies 54,
20 55, can include a shaping portion 54(a), 55(a) which, when pressed together, may form a desired pleat tip region shape. For example, when pressed together, cooperating shaping portions 54(a), 55(a) may cooperate to form any of the pleat tip region shapes previously mentioned (e.g., pointed, tapered, rounded). This pressing can also bond facing surfaces of the pleat tip region together (e.g., by causing the facing surfaces to contact each other and
25 liquefy). Although the shaping apparatus 57 illustrated in Figure 5 has two dies 54, 55, the

shaping apparatus 57 may include any suitable number of dies cooperating to form a desired non-bulbous pleat tip region shape. For example, the shaping apparatus 57 may include three dies, which cooperate to form a desired pleat tip region shape.

Although the shaping apparatus 57 may reform the pleat tip regions solely by the application of pressure, the shaping apparatus 57 or the dies 54, 55 of the shaping apparatus 57 may include additional reforming devices (not shown), such as electromagnetic or sonic energy generating devices (e.g., an electric or radiant heater, an ultrasonic generator). For example, one or both of the dies 54, 55 of the shaping apparatus 57 may include a heating device so that heat can be supplied to the pleat tip region being reformed. Heat and pressure from the dies 54, 55 can work in combination to soften and melt the material in the pleat tip region of the pleat, thus increasing the speed and decreasing the difficulty of the reforming process. If heat and pressure are used to reform the pleat tip regions of the pleats, heat and pressure can be applied sequentially (e.g., first heat and then pressure, or the reverse) or concurrently.

In addition, although the shaping apparatus 57 illustrated in Figure 5 includes a pair of dies 54, 55, the shaping apparatus need not include movable dies or the application of pressure. The shaping apparatus may reform the pleat tip regions solely by the application of heat. For example, the shaping apparatus may comprise a device such as an ultrasonic energy generating device and no dies, so that ultrasonic energy is the primary method for reforming the pleat tip region of the pleat.

An illustrative method for reforming the pleat tip regions of a pleated filter medium or composite can be described with reference to Figure 5. A pleated filter medium or composite 51 can initially be formed by pleating a sheet of filter medium or composite with a corrugator (not shown), which may or may not be in operative communication with the shaping apparatus 57. For example, a porous sheet of filter medium or composite can be corrugated

through a conventional corrugator, thereby forming a pleated filter medium or composite 51 having pleat tip regions, which may include a bulbous shape. For example, one or more layers comprising the filter medium or the filter composite may be formed into a laminate or composite and then co-corrugated to produce a plurality of pleats. Beginning at one end of the plurality of unreformed pleats 51, an individual pleat 58 may be arranged to separate or position the pleat tip region away from the other pleats so that the pleat tip region may be conveniently introduced to the shaping apparatus 57. Once the pleat tip region of the individual pleat 58 is positioned between the dies 54, 55 of the shaping apparatus 57, one or both of the dies 54, 55 of the shaping apparatus 57 may reform the pleat tip region by moving toward each other and toward the pleat tip region in directions generally perpendicular to the pleat 58. Heat and/or pressure can then be applied to the opposing outer surfaces of the pleat tip region to reform it, e.g., fashion it in any of the previously mentioned shapes embodying the invention. Once the pleat tip region is reformed, one or both of the dies 54, 55 can move away from the pleat 58, releasing the reformed pleat tip region. The pleat 58 having the reformed pleat tip region can then be repositioned adjacent to other pleats 52 having reformed pleat tip regions. This process may be repeated until a desired number (e.g., substantially all) of the pleat tip regions along one side of the pleated filter medium or composite 51 have been reformed.

Figures 6-8 show one example of a process for forming a filter pack. In the methods illustrated in Figures 6-8, a spacer 59, such as a woven or nonwoven fabric or mesh, is inserted within each pleat and/or between adjacent pleats of the pleated filter medium or filter composite to form a filter pack. Figure 6 shows a method for forming a filter pack having a spacer and a pleated filter medium or filter composite with reformed pleat tip regions. The shaping apparatus 57 shown in Figure 6 may be similar to the shaping apparatus described in Figure 5. Like the method shown in Figure 5, an individual pleat 58 can be positioned away

from other pleats 51 and the pleat tip region of the positioned pleat 58 can be introduced between the dies 54, 55 of the shaping apparatus 57. The dies 54, 55 can then reform the pleat tip region by applying heat and/or pressure to the opposing outer surfaces of the pleat tip region. After the pleat tip region is reformed, the pleat tip region may have facing surfaces contacting and/or bonded to each other. As the pleat 58 is repositioned onto the stack of pleats 52 having reformed pleat tip regions, a spacer 59 may be placed between the pleat having a previously reformed pleat tip region and the pleat 58 most recently having its pleat tip region reformed. The relatively wide space created between the positioned and repositioned pleats can also permit the pleat faces to be treated (e.g., coated with an adhesive) in a quick and efficient manner, if desired. Subsequently, the pleat 58 having the reformed pleat tip region can be repositioned adjacent to the spacer 59. This process can be repeated to form a filter pack 53 having plurality of spacers 59 between adjacent pleats, and a pleated filter medium or filter composite having reformed pleat tip regions.

While the method illustrated in Figure 6 shows a spacer inserted between adjacent pleats immediately after each pleat tip region is reformed, alternative embodiments may insert the spacer after the reformed pleat is repositioned or before the pleat tip region is reformed, e.g., immediately before. For example, Figure 7 shows another method for forming a filter pack 62. The shaping apparatus 57 may be similar to the previously described shaping apparatus. However, unlike the previously described embodiments, a plurality of spacers 59 are positioned between adjacent pleats and/or within each pleat before the pleat tip regions are reformed. When the pleat tip region of a pleat 58 is reformed with a spacer within the pleat 58, the spacer and the filter medium or filter composite may be integrally attached or bonded at the pleat tip region. For example, the spacer 59 in the pleat 58 having its pleat tip region reformed may comprise a material with a lower melting point than the surrounding filter medium or filter composite portions. During the reformation of

the pleat tip region by the dies 54, 55 of the shaping apparatus 57, the material of the spacer can melt and impregnate the surrounding filter medium or filter composite. The resulting reformed pleat tip region can comprise an inter-bonded structure of filter medium or filter composite material and spacer material. This inter-bonded structure can result in a pleat tip region with increased structural stability and a decreasing ability to reform into a bulbous-shape. After the pleat tip region of the pleat 58 is reformed, the reformed pleat tip region can be removed from the shaping apparatus 57 and repositioned next to other pleats with reformed pleat tip regions to form a filter pack 62. After the desired number of pleat tip regions on one side of the filter pack 62 have been reformed, the pleat tip regions on the other side of the formed filter pack 62 may be reformed in a similar or different manner.

In the previous embodiment, the spacer was bonded within each reformed pleat tip region. Alternatively, a spacer may be positioned within a pleat or between pleats, but not be bonded within the pleat tip region. For example, a spacer may be present within a pleat between the legs of the pleat, but not between facing surfaces of the pleat tip region. In this instance, the spacer is within the pleat, but is largely unaffected by the pleat tip region reforming procedure. In this regard, the spacer may occupy substantially all or a portion of the space between pleats or within a pleat.

Figure 8 shows another embodiment of the invention. The system shown in Figure 8 includes first and second shaping apparatuses 57(a), 57(b) on opposing sides of a conveying apparatus 81. The conveying apparatus 81 can define a serpentine-like conveying path with one or more curves such as oppositely bending curves 81(a), 81(b), 81(c). In the illustrative method, a pleated filter medium or composite 61 having unreformed pleat tip regions can be conveyed in a path defined by the conveying apparatus 81. As the pleated filter medium composite 61 having unreformed pleat tip regions approaches a first curve 81(a) in the path defined by the conveying device 81, the pleats or the spaces on the first side of the pleated

filter medium or filter composite 61 can gradually open, and spacers 59 may be inserted in the spaces between the pleats. The pleated filter medium or filter composite 61 and the spacer(s) 59, can then travel towards the first shaping apparatus 57(a) which may be positioned proximate a second curve 81(b) in the path defined by the conveying device 81.

5 As the pleated filter medium or composite 61 approaches the curve 81(b), the pleats or spaces on the second side of the pleated filter medium or filter composite 61 gradually open. The first shaping apparatus 57(a) can then reform the pleat tip regions on the second side in any suitable manner such as those previously described. Additional spacers 59 can also be inserted between the spaces or pleats on the second side. The pleat tip region reforming
10 process can be repeated until the desired number of pleat tip regions, preferably all of them, have been reformed.

Then, the pleated filter medium or composite 61 can travel towards a second shaping apparatus 57(b) located proximate a third curve 81(c) defined by the conveying apparatus 81. The second shaping apparatus 57(b) can be located on the first side of the conveying
15 apparatus 81, opposite the first shaping apparatus 57(a). As the pleated filter medium or composite having reformed pleat tip regions on the second side approaches the curve 81(c), the spaces or pleats on the first side, i.e., the side having unreformed pleat tip regions, gradually open. Once the spaces between the pleats have opened, the second pleat shaping apparatus 57(b) can reform the unreformed pleat tip regions on the first side in any suitable
20 manner such as those previously described. The filter pack 62 leaving the second shaping apparatus 57(b) may have a pleated filter medium or filter composite with reformed pleat tip regions on both sides, and spacers 59 between and/or within the pleats. Thus, the system shown in Figure 8 can produce a filter pack in a continuous and efficient manner.

The filter medium may be selected in accordance with several factors, including the
25 nature of the fluid being filtered, the nature and size of the contaminants in the fluid, and the

acceptable pressure drop across the filter medium. The filter medium may comprise a wide variety of porous microfiltration or ultrafiltration media. The filter medium may consist of only a single sheet or layer or it may comprise multiple sheets and/or layers. If the filter medium comprises multiple layers, it is not necessary that all layers have the same material, shape, thickness or structure.

The filter medium may include any suitable structure and/or material. For example, the filter medium may be a porous sheet such as a supported or unsupported membrane, or a woven or nonwoven fibrous or filamentous sheet, and may be fabricated from a natural or synthetic polymer, glass, ceramic or metal. Preferably, the filter medium comprises a polymeric material, more preferably a fibrous polymeric material, which is substantially free of boron. Polymeric materials may include polyolefins such as polypropylene and polyethylene; fluoropolymers such as PTFE, fluorinated ethylenepropylene (FEP), and perfluoroalkoxy polymers (PFA); polyamides such as nylon and polyaramid; and polyesters. Advantageously, polymeric filter media are less likely to splinter and break than other filter media (e.g., glass), and are less likely to produce contamination (e.g., boron containing contaminants). Other preferred media may include a family of fibrous filter media having various binder resins, and are available from Pall Corporation under the trade names Ultipor® and Pallflex®. Further, the filter medium may be a porous sintered sheet of metallic or ceramic material, such as a sheet of sintered metal powder, fibers and/or filaments.

Furthermore, the filter medium may have any desired pore structure, including a graded pore structure, and any desired nominal pore size. The filter medium may also include an electrostatic charge (e.g., an electret filter medium). By providing an electrostatic charge to the filter medium, particulate contaminants can be trapped electrically as well as

mechanically. For example, a temporary or permanent electrical charge can be imparted to a polypropylene melt-blown nonwoven web.

The filter medium can also have any suitable removal rating or filtration efficiency. Preferably, the filter medium has high filtration efficiency. For example, the filter medium may have a HEPA (high efficiency particulate air), an ULPA (ultra low penetration air) or a super ULPA removal rating. Preferably, the filter medium can have a removal rating up to 0.1 or 0.3 microns or more, of R, where R is any rational number greater than or equal to about 85% and less than or equal to 100%. Exemplary values of R include: 85.0, 90.0, 95.0, 97.0, 99.5, 99.9, 99.97, 99.997, 99.999, or 99.9999 percent. If the filter medium comprises plural layers, one or more layers may have a HEPA, ULPA, or super ULPA rating. The desired removal rating of the filter medium may depend on the environment in which the filter is employed. For example, particulate filters used in aircraft preferably have a removal rating of at least about 85%, and in clean rooms at least about 99.997%.

The filter medium may form part of a filter composite. In addition to a pleated filter medium, a filter composite may optionally include one or more drainage layers upstream and/or downstream of the filter medium, and/or cushioning layers between the one or more drainage layers and the filter medium.

If the filter composite includes drainage layers, the drainage layers are preferably very open, allowing fluid to flow laterally and to uniformly distribute the fluid across the surface of the filter medium. Thus, the drainage layers typically have a very low edgewise flow resistance, and are much coarser than the filter medium. The drainage layers can also prevent pleated surfaces of the filter medium from coming into contact with one another and thereby reducing the effective surface area of the filter medium. The drainage layers can thus provide positive spacing between adjacent pleats of the filter medium. Further, the drainage layers

can be loose or one or more drainage layers can be laminated to one another to provide stiffness to the filter composite and/or improve the shape of the pleat.

Any suitable woven or nonwoven material having good porosity can be used for an upstream drainage layer and/or downstream drainage layer. Furthermore, either layer may be fabricated from one or more of natural fibers, polymeric materials, and/or glass fibers. In a preferred embodiment, the upstream drainage layers comprise mesh, such as an extruded polymeric mesh. The mesh can be fabricated from any polymeric material, including polyester, polypropylene, or polyamide such as nylon, which is suitable for the fluid being filtered and for the applicable filtration parameters such as temperature. The mesh is preferably as smooth as possible to reduce abrasion between it and the underlying layers. Extruded polymeric mesh is generally preferable to other support and drainage materials, including woven and nonwoven fibrous webs and polymeric netting, because it is so smooth and has such a low edgewise flow resistance and because it typically does not shrink during fabrication and corrugation of the filter element.

A principal purpose of the cushioning layer is to prevent abrasion between the drainage layer and the filter medium. The drainage layer typically has good drainage properties because it is fashioned from relatively large fibers or filaments. Consequently, it generally has a rougher surface than the filter medium. When such a material is laminated directly to the filter medium, for example, significant abrasion of the filter medium may result when the filter medium undergoes flexing, for example, due to pressure cycles, and the drainage layer repeatedly rubs against the filter medium. However, when a cushioning layer, which is smoother than a drainage layer and tougher than a filter medium, is interposed between a drainage layer and a filter medium, the abrasion of the filter medium can be greatly reduced, resulting in an increase in the useful life of the filter medium, or corresponding filter pack or filter element.

The cushioning layer is preferably formed of a thin, very porous material. It is also preferably formed from a material which can be characterized as smooth or as smooth and tough. For example, it may be a non-abrasive, nonwoven material with a high tensile strength. A preferred material for the cushioning layer is a wet-laid polyester nonwoven material sold by Hirose Corporation under the trade designation 05TH08. Other preferred materials include a nylon nonwoven material available from Fiberweb North America Inc. under the trade designation Cerex and a nonwoven polyester material available from Reemay Corporation under the trade designation Reemay, such as Reemay 2006 or Reemay 2250.

A filter pack according to embodiments of the invention may include any of the above described filter media or filter composites (e.g., filter laminates). In addition, a filter pack may optionally include spacers. Spacers may include any suitable article which can space surfaces of adjacent pleats or surfaces of a pleat. Exemplary pleat spacers may include combs or structures which fit over the tips of the pleats, or structures such as polymeric beads (e.g., hardened adhesive) or fibrous media (strips) which may lie between the pleats to maintain pleat spacing. Pleat spacers may even include structures, such as dimples or ridges, which are integrally formed in the pleats, for example, in the legs of the pleats, to space adjacent pleat surfaces.

A pleated filter medium, filter composite, or filter pack according to embodiments of the invention can be incorporated into any suitable filter element and can be used in any suitable form. The shape of the filter element is not restricted and may be cylindrical, for example, or parallelepiped. In a preferred embodiment, the filter element may include a frame (e.g., a box-shaped frame) having a pleated filter medium or filter composite including a pleated filter medium or composite disposed in and sealed against the frame. For example, a pleated filter composite having pleat tip regions with a predetermined shape (e.g., tapered) can be mounted within and sealed to a wood, plastic, or metal frame with a potting material

such as polyurethane, epoxy, silicone, hot-melt adhesive or plastisol. A filter element having a framed pleated filter medium, filter composite or filter pack can be used, for example, to purify the air or an aircraft cabin or a clean room.

Alternatively, the filter element may comprise a cylindrical structure. A cylindrical
5 filter element may include a previously described pleated filter medium or composite formed in a cylinder around a rigid cylindrical core. Pleat tip regions embodying the invention may be incorporated only at the radially inward roots of the pleats, only at the radially outward crests of the pleats, or both. End caps may secure the cylindrical pleated filter medium to the rigid cylindrical core. If desired, a wrap, cage or other support structure may be disposed
10 around the cylindrical, pleated filter medium or filter composite. Preferably, the filter element can be removable and replaceable when the filter element outlives its useful life (e.g., becomes fouled or damaged).

While the invention has been described in some detail by way of illustration and example, it is understood that the invention is not restricted to the specifically described
15 embodiments in the specification. For example, the present invention encompasses the combination of one or more of the features of any of the embodiments previously described or illustrated with one or more of the features of the other embodiments. Thus, a pleat described or illustrated for any of the embodiments (e.g., Figure 4(a)) may be combined in a filter with a pleat described or illustrated for another embodiment (e.g., Figure 4(c)) and still
20 be encompassed by the invention. The present invention also encompasses any of the embodiments previously described or illustrated where one or more of the features of the embodiment are modified or deleted. As an example, the spacer 45 described and illustrated for the embodiment shown in Figure 4(c)) may be deleted and the pleat is still encompassed by the invention. Thus, the invention includes all modifications, equivalents, and alternatives
25 falling within the spirit and scope of the invention.

Claims:

1. A filter comprising:

a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region, wherein a thickness of the pleat tip region at a point spaced about one to four pleat leg thicknesses from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness.

2. A filter comprising:

a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region, wherein a thickness of the pleat tip region at a point spaced about one to four pleat leg thicknesses from the end of the pleat tip region is less than or equal to a distance between corresponding points on opposing outer surfaces of the pleat legs.

3. A filter comprising:

a pleated structure having a plurality of pleats and more than one layer, at least one of the pleats having a reformed pleat tip region.

4. A filter comprising:

a pleated structure having a plurality of pleats and a pair of pleat legs, at least one of the pleats having a reformed pleat tip region and contacting pleat legs.

5. A filter comprising:

a plurality of pleats, at least one pleat including a pleat tip region having contacting inner surfaces.

6. A filter comprising:

a pleated porous sheet having a polymeric material and a plurality of pleats, at least one pleat including a pair of pleat legs and a pleat tip region, wherein the sheet includes a pre-scored region at the pleat tip region.

7. A method of making a filter comprising:

forming a plurality of pleats having pleat tip regions; and
applying pressure to opposing outer surfaces of at least one pleat tip region.

8. A method of making a filter comprising:

forming a plurality of pleats free of bulbous pleat tip regions.

9. A method of making a filter comprising:

forming a plurality of pleats wherein a thickness of each pleat tip region at a point spaced about one to about four pleat leg thicknesses from the end of the pleat tip region is less than or equal to about twice the pleat leg thickness.

10. A method of making a filter comprising:

forming a plurality of pleats wherein a thickness of each pleat tip region at a point spaced about one to about four pleat leg thicknesses from the end of the pleat tip region is less than or equal to a distance between corresponding points on opposing outer surfaces of the pleat legs.

11. A method of making a filter comprising:
scoring a porous sheet including a polymeric material; and
pleating the porous sheet.
- 5 12. An apparatus comprising:
one or more dies arranged to reform a pleat tip region of a pleat.
- 10 13. A filter made by the method or apparatus of any of claims 7-12.
14. The filter, method or apparatus of any of the preceding claims wherein the filter includes
pleat legs generally parallel to each other.
- 15 15. The filter, method or apparatus of any of the preceding claims wherein the filter
comprises a fluoropolymeric material.
16. The filter, method or apparatus of any of the preceding claims wherein the filter includes
more than one layer.

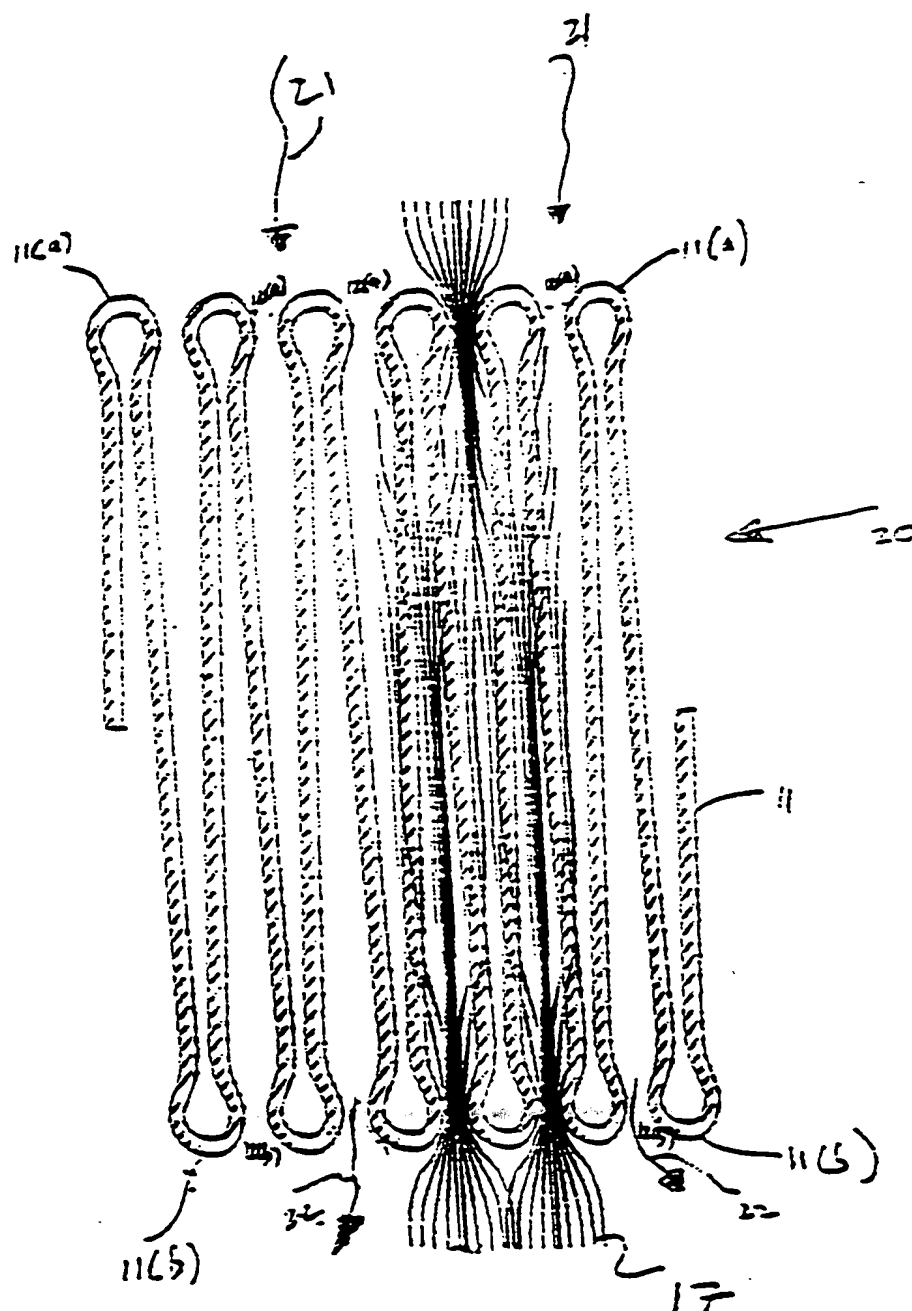


Fig 1

FIG 2(a)

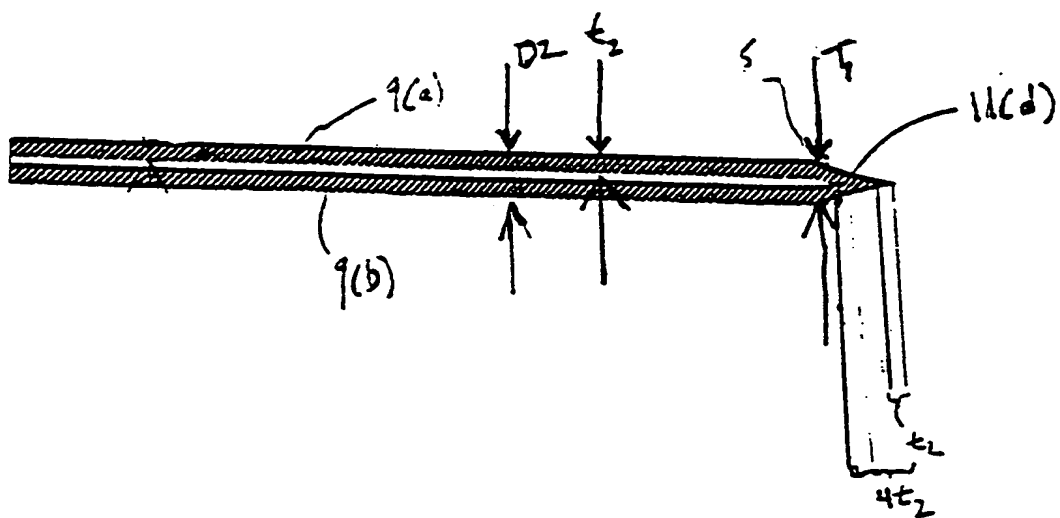
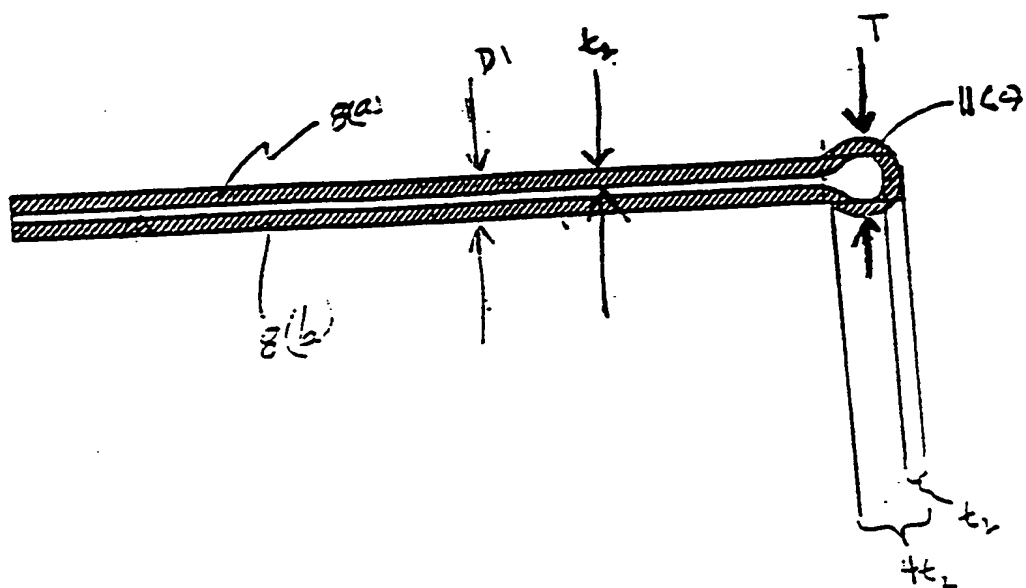


FIG 2(b)

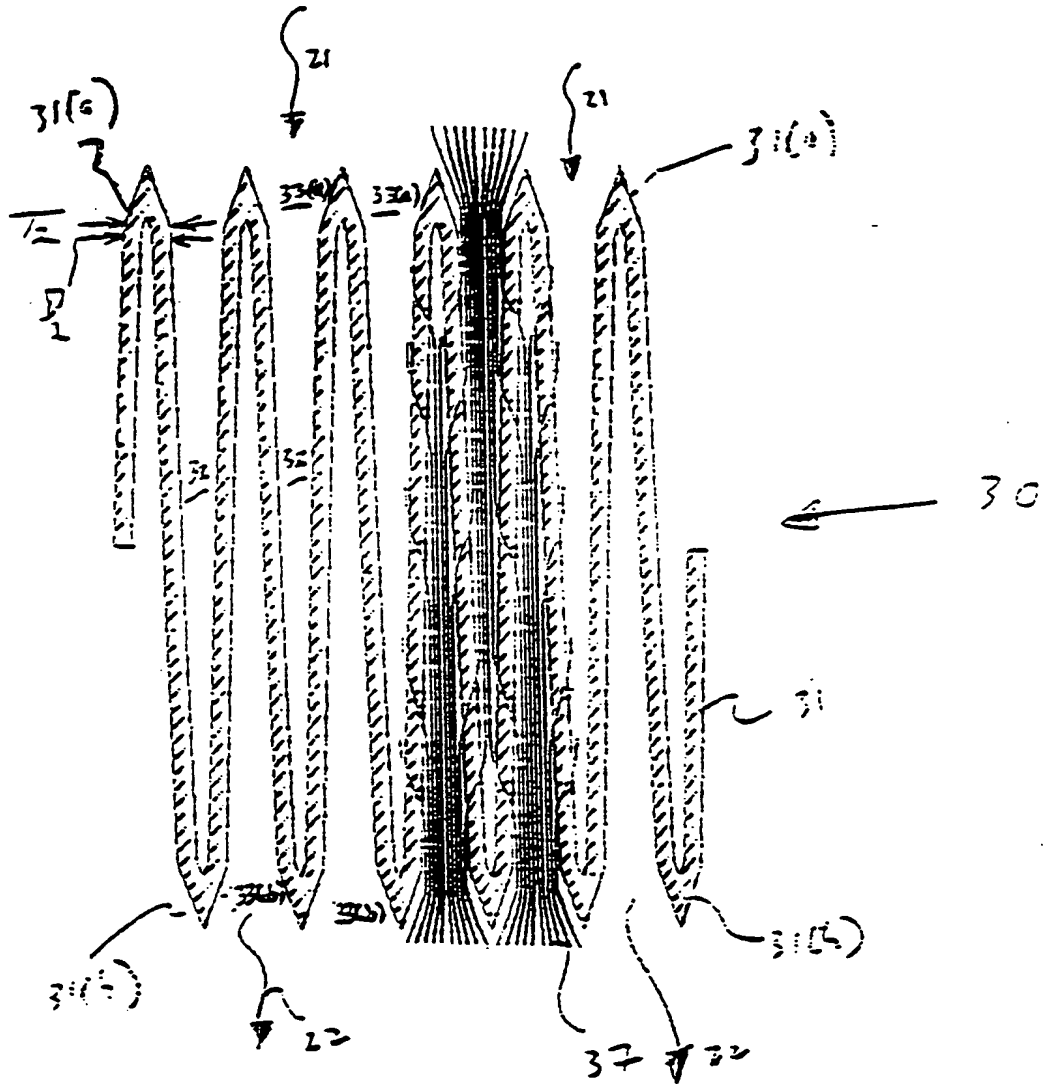


FIG 3

FIG 4(a)

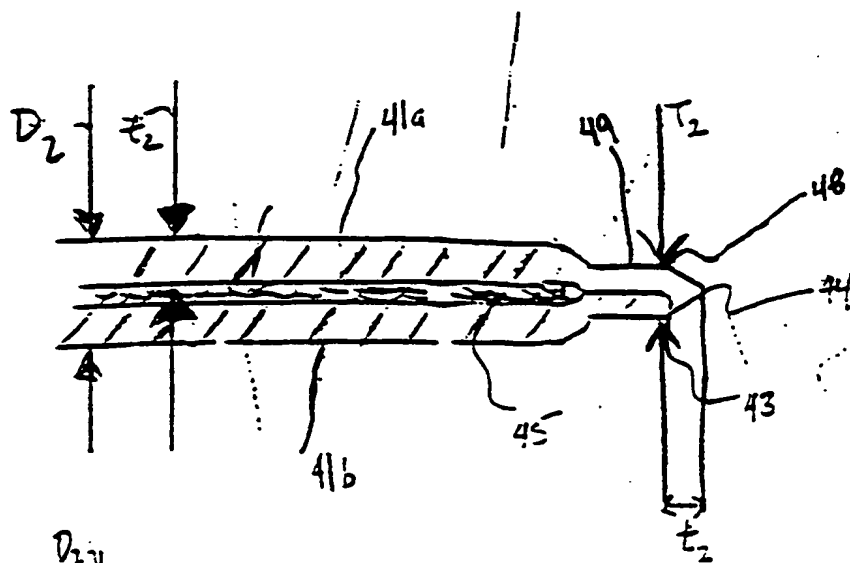


FIG 4(b)

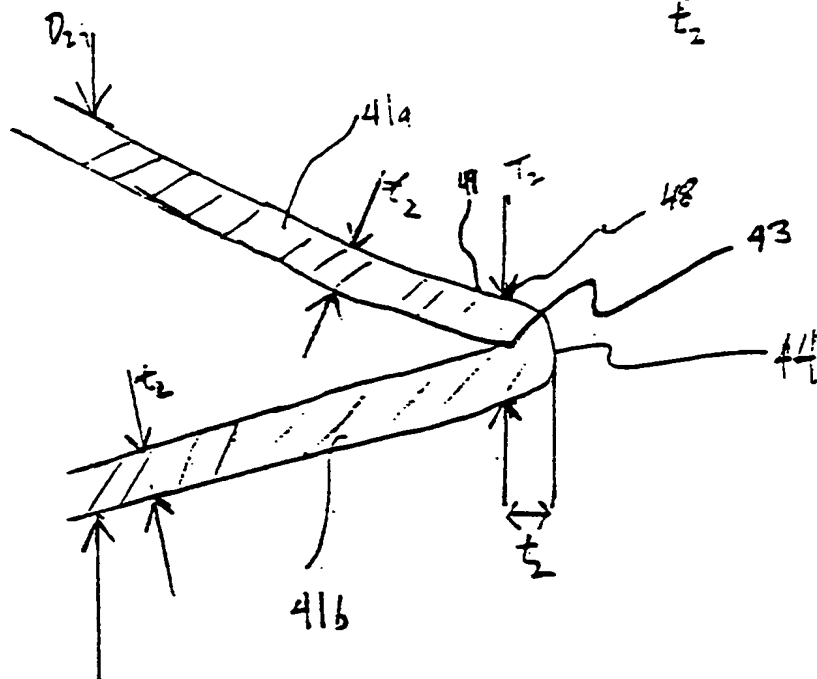


Fig 1(c)

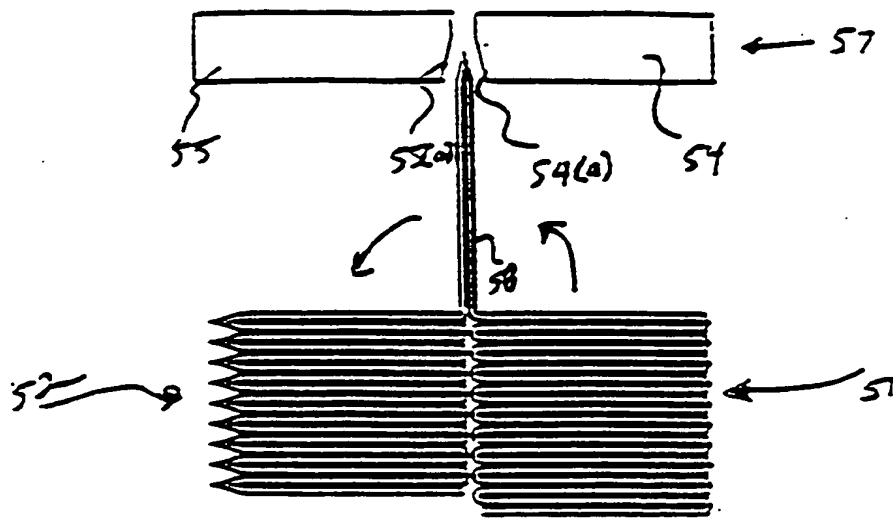


FIG 5

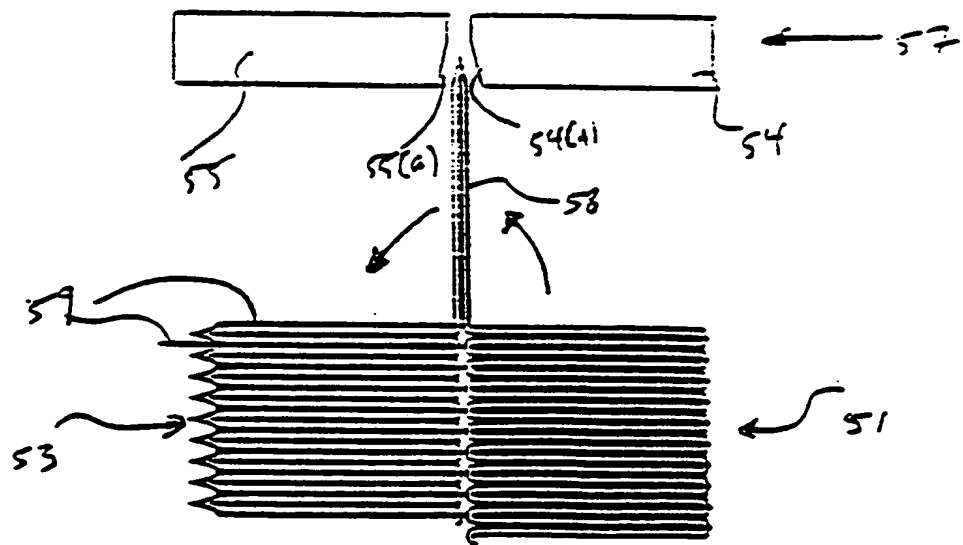


FIG 6

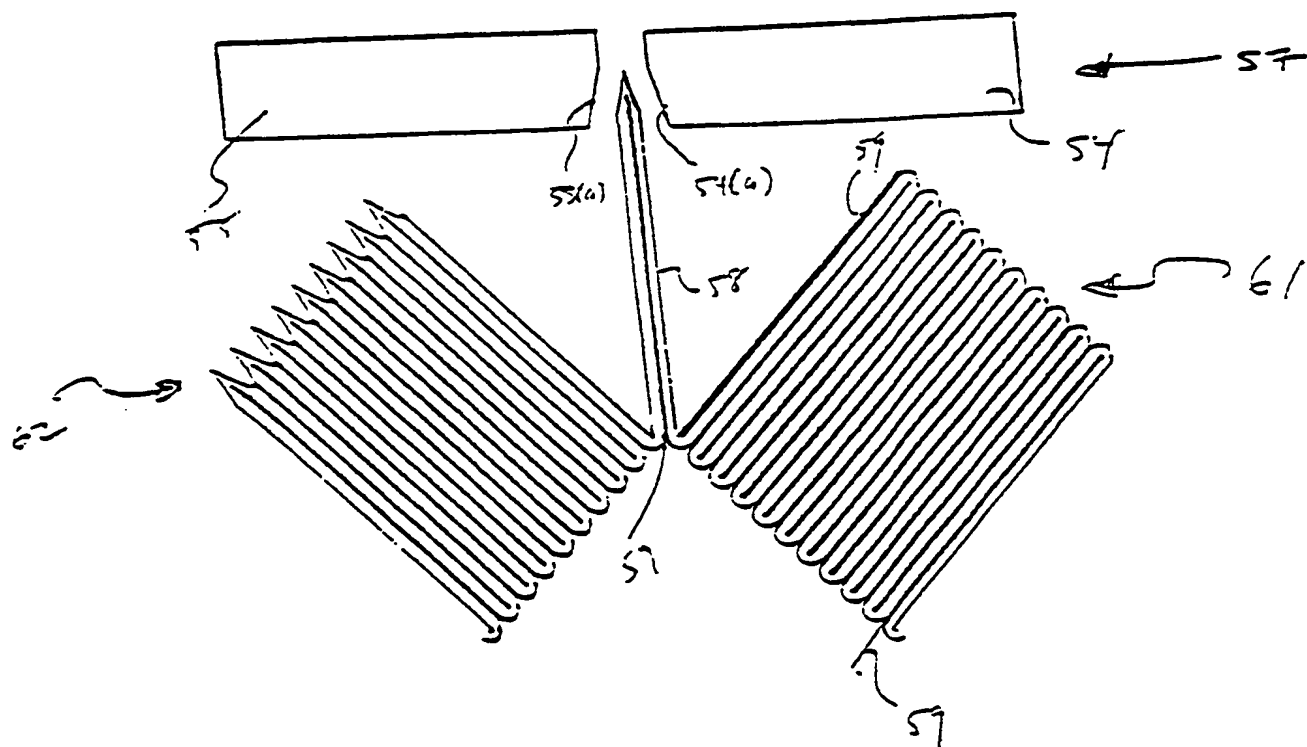


FIG. 7

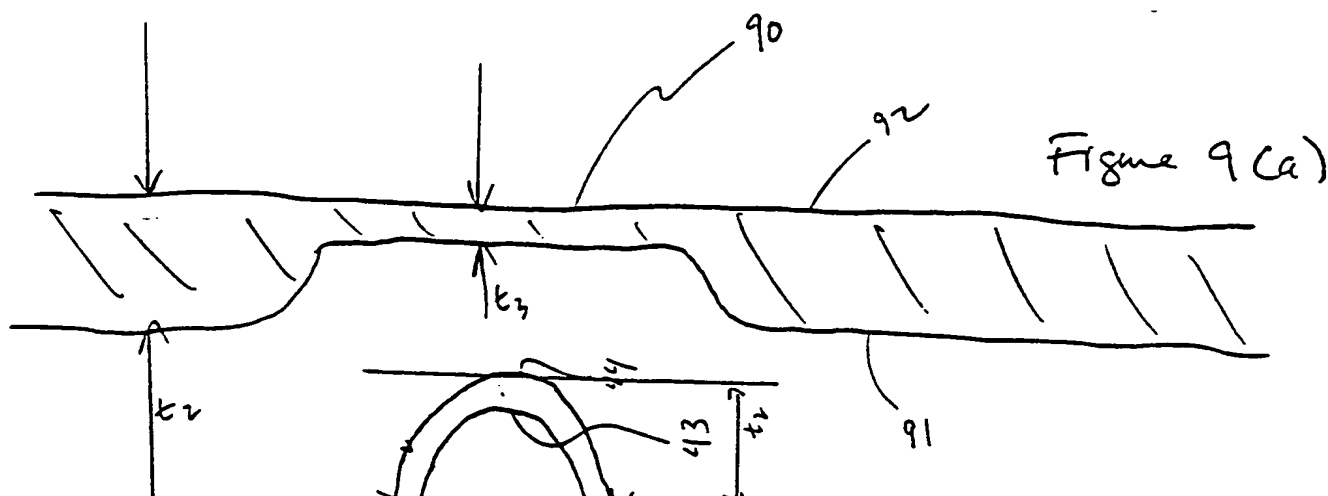


Figure 9(a)

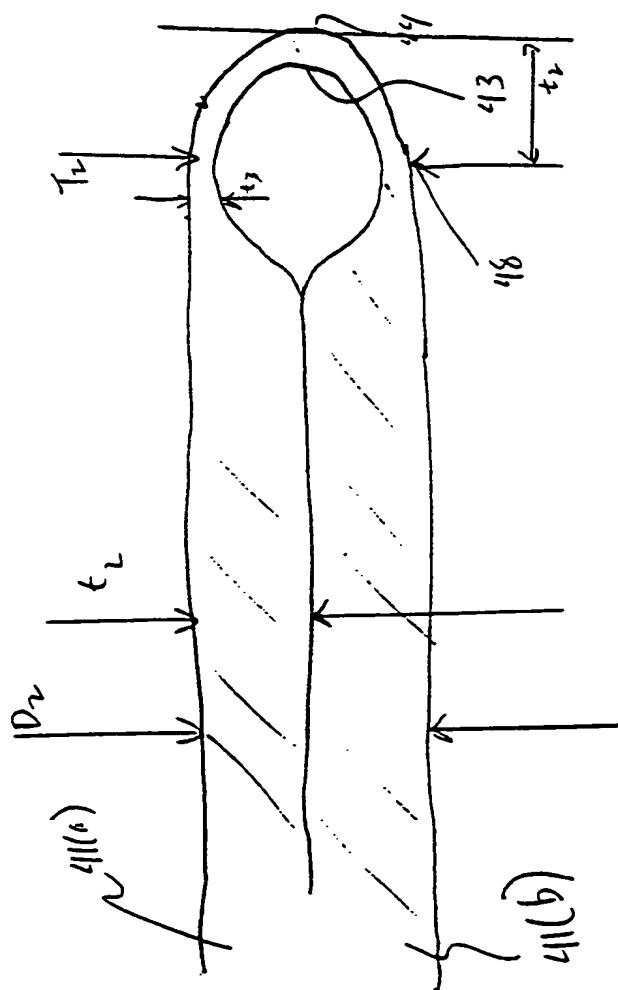
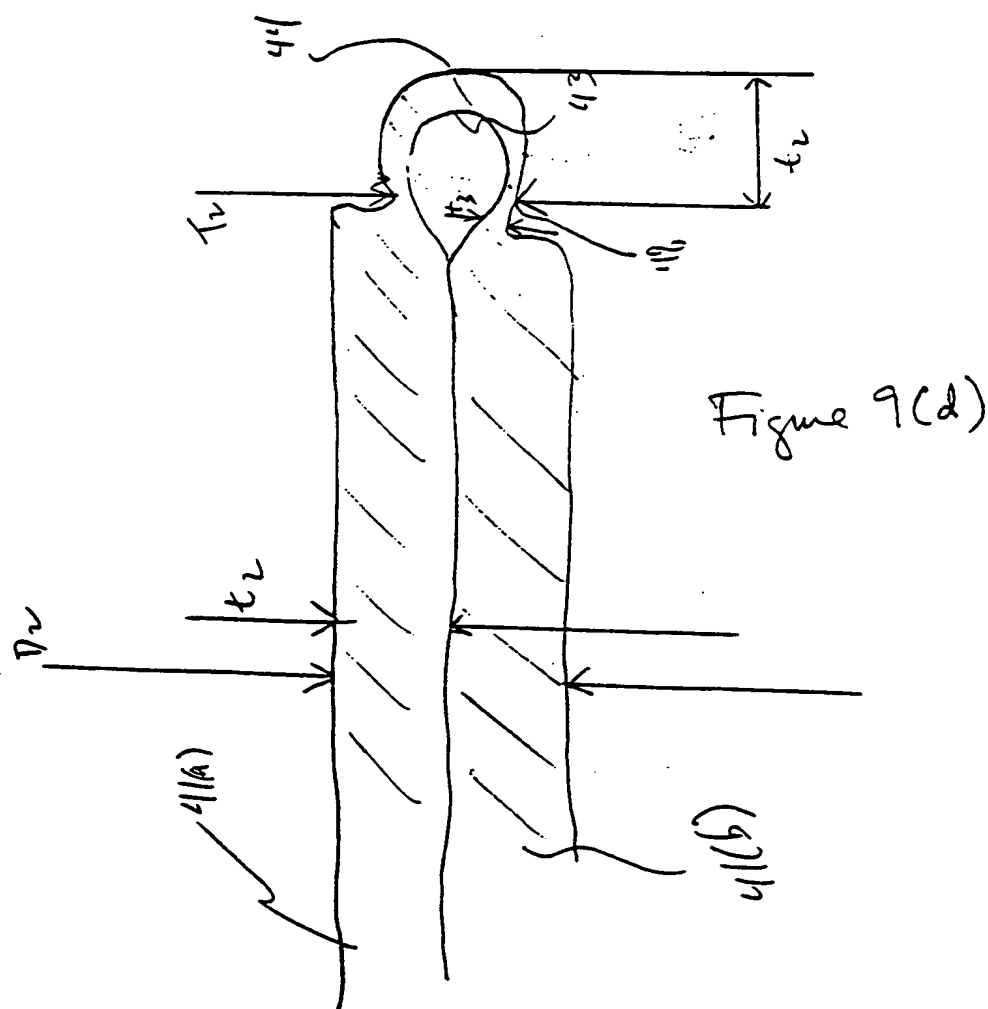
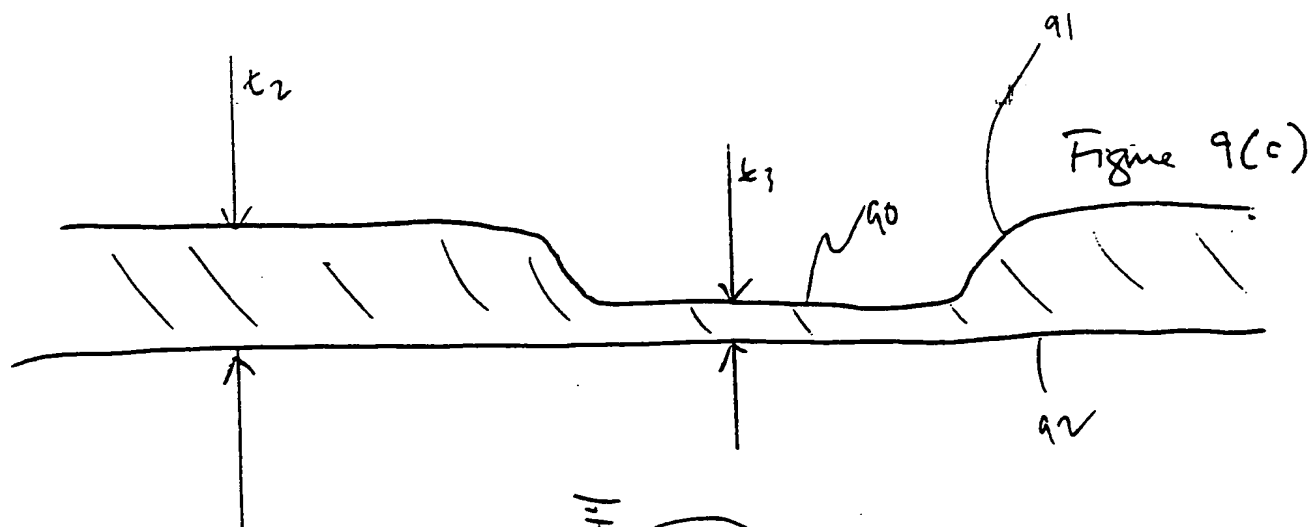
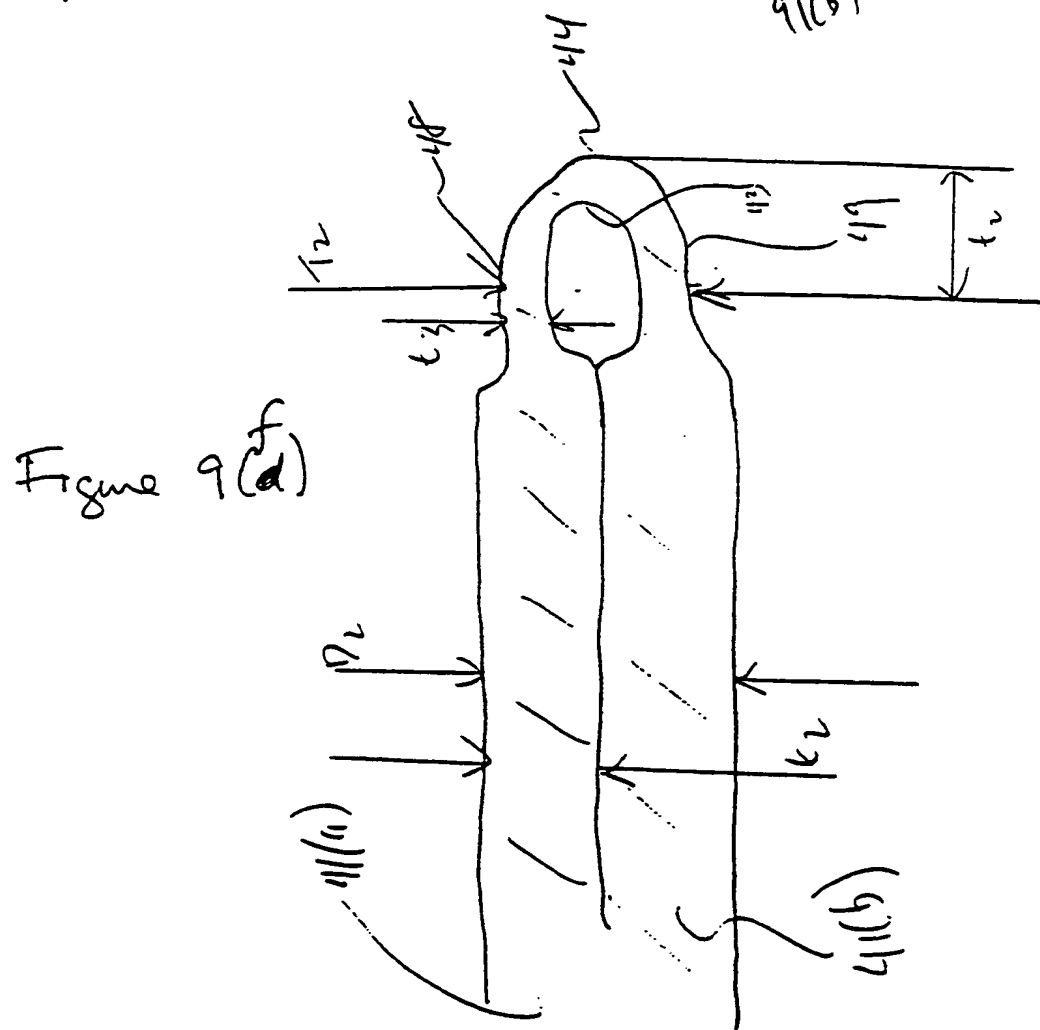
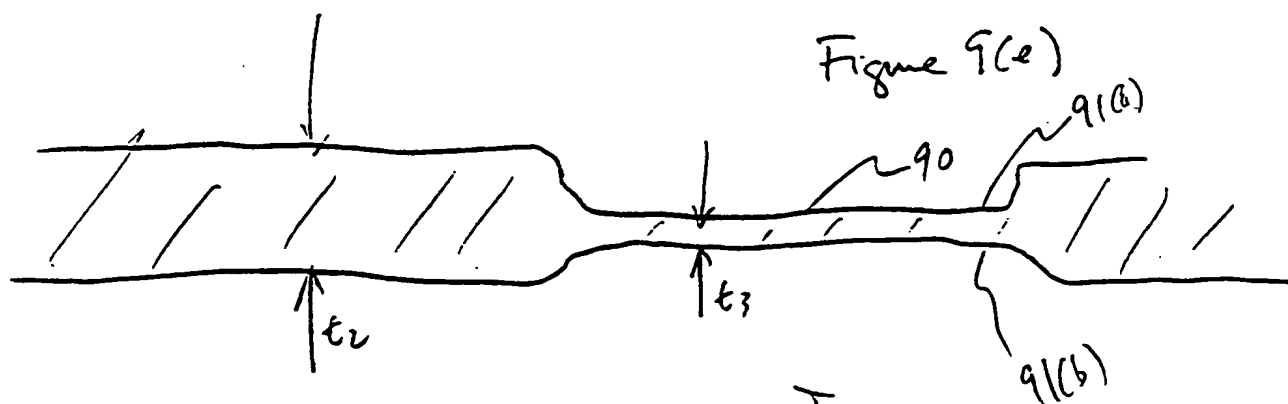


Figure 9(b)





INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/14439

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B01D46/52

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 702 801 A (CHIEN JUNG-FU) 30 December 1997 (1997-12-30) column 2, line 11; figures 9,17	1-11,13, 14,16
X	GB 2 225 543 A (ENVAIR) 6 June 1990 (1990-06-06) figure 2	1,2, 8-11,13
X	EP 0 692 294 A (NIPPON DENSO CO) 17 January 1996 (1996-01-17) page 4, line 19-22; figure 2	1-3,6-13

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

21 October 1999

Date of mailing of the international search report

29/10/1999

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Polesak, H

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 99/14439

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